SALINE WATER RESEARCH PROGRAM

HEARINGS

BEFORE THE

SUBCOMMITTEE ON IRRIGATION AND RECLAMATION

OF THE

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS HOUSE OF REPRESENTATIVES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

FOR THE

PURPOSE OF REVIEWING PROGRESS MADE UNDER THE SALINE WATER RESEARCH PROGRAM

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SALINE WATER RESEARCH PROGRAM

THURSDAY, MARCH 7, 1957

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON IRRIGATION AND RECLAMATION OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D. C.

The subcommittee met, pursuant to call, at 10:15 a. m., in the committee room, New House Office Building, Hon. Wayne N, Aspinall (chairman of the subcommittee) presiding.

Mr. ASPINALL. The Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs will be in session for the taking of testimony and further consideration of the saline water research program.

The chairman has a short statement that he wishes to make, and then if any member of the committee wishes to make one afterward, it will be in order.

Because the Interior and Insular Affairs Committee has surveillance of the saline water research program, this hearing has been called to review the program with officials of the Department of the Interior and try to determine just where we stand with respect to finding ways and means of economically converting salt and brine water to fresh water.

As many of us recall, this research program was initiated by enactment of the Saline Water Act of 1952. This initial act called for the expenditure of $2 million over a 5-year period to carry on research in this field.

About 2 years ago the need developed for modifying the initial legislation to extend the program, permit more flexibility in the operations, and authorize additional funds. Legislation to accomplish this, authored by Mr. Engle, was enacted.

The program was extended to 1963 and an additional $8 million was made available. I believe that we all hoped at that time that this additional authority and additional money would reflect a speedup in meeting objectives of the program.

The committee reports implementing the legislation expressed an urgent need for progress and the hope that everything possible would be done to meet the objectives of the program at an early date.

One factor which prompted this hearing is the uncertainty as to just where we do stand currently in this program. There have been conflicting reports.

The Secretary of the Interior on several occasions recently has painted a very optimistic picture of the progress being made. Several press statements and magazine articles on the subject, presumably based on information furnished by Department officials, have likewise been optimistic.

On the other hand, such optimism does not appear to be supported by the official reports of the Department submitted to this committee. For instance, the report for the year 1954, submitted over 2 years ago, indicated that the initial goal of converting sea water for municipal and industrial uses for $125 per acre-foot was in sight.

The report for 1955 indicated that conversion costs were being greatly lowered by new processes and improvements in old processes. Yet, in the report for 1956, the year just concluded, the most optimistic estimate of cost given was $165 per acre-foot. I think that the committee is due some explanation of these apparent inconsistencies.

In addition to the committee's desire to know just where we stand in this program, there is the additional question as to whether the program is receiving the degree of urgency it deserves.

May I say a degree of urgency which this committee has expressed time and time again.

Two years ago, as I pointed out a minute ago, Congress expressed a very definite need for urgent action. I think that the committee should know the Department's view as to whether the program warrants such action. I think that we all recognize that in this type of development, when time permits, it is more economical to perform rather complete research before large-scale pilot plants are undertaken. The question involved here is whether we can afford the time.

If there is no objection, I would like to insert at this point in the record a copy of the letter from the chairman of the full committee to Assistant Secretary Aandahl requesting this hearing.

(The letter follows:)

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
HOUSE OF REPRESENTATIVES,
Washington, D. C., February 27, 1957.

Mr. FRED G. AANDAHL,
Assistant Secretary of the Interior,
Department of the Interior,
Washington, D. C.

DEAR MR. AANDAHL: In these days of drought and water shortages when more and more importance is being placed upon our limited water resources, when the President makes special mention in his state of the Union message that water is rapidly becoming our most precious natural resource, when it is fast becoming apparent to all that we must develop new sources of fresh water, I believe it appropriate that we determine just where we stand in the program to find ways and means of economically converting sea water to fresh water.

This committee and I personally have followed closely the progress of this program since it was authorized in 1952 and made the responsibility of the Secretary of the Interior. Two years ago we amended the Saline Water Act of 1952 providing an additional $8 million and flexibility of operations. We hoped that this additional authority would reflect a speedup in meeting the objectives of the program. As you may recall, the conference report on the legislation carried this statement of the House managers:

"The Nation's rapidly increasing population and expanding industry, with the corresponding rapidly increasing needs for water, the critical water situations that have developed in many areas in recent years, and national and international conditions in this atomic age all reflect the imperative need for speeding the objectives of this program. It may become necessary within the term of this program for many areas to depend on salt or saline water conversion for a water supply. Ways and means must be found without undue delay for economically converting salt or saline water to fresh water. The program cannot be allowed to drift along without producing concrete results, and it is expected that with the expanded implementation of the saline-water program authorized by this legislation results will be obtained."

The Senate report on the legislation carried similar language.

Nevertheless, recent reports do not indicate the progress hoped for. Several on the committee have expressed disappointment. There appears to be a feeling that the program is not receiving the degree of urgency it deserves or which the Congress expected.

In view of the above, I believe it would be mutually beneficial for the committee, because of its responsibility for surveillance of this program, to review the program with you. Congressman Aspinall, chairman of the Reclamation Subcommittee, has set aside March 7 and 8 for this purpose. The committee would like to discuss the program with you and the program director. Also, if possible, the committee would like to question Mr. W. L. Badger or representative relative to the long tube vertical evaporator which he proposes, and perhaps representatives from 1 or 2 additional firms whose research appears to be producing favorable results.

Would you please advise me with respect to your appearance. Also, I would appreciate any comments you may have in this connection.

Sincerely yours,

CLAIR ENGLE, *Chairman.*

Mr. ASPINALL. Mr. Aandahl is present here this morning. With the committee's permission, unless there is an objection, we shall hear from the Honorable Fred G. Aandahl, Assistant Secretary of the Interior, then from David S. Jenkins, Director, Office of Saline Water, the Department of the Interior, and then from Mr. E. H. Sieveka, Mr. A. Cywin, Dr. George Lof, Dr. W. S. Gillam, Mr. J. J. Strobel, and Mr. W. L. Badger, the latter six being either specialists or contractors in this program.

After we have heard from all of these with their direct presentation, we will have them before our committee for questioning by members of the committee. The reason that I do this is because there will be several questions which will come up which will more than likely be answered by the representatives of the Department or by the specialists involved, and to repeat those questions I think would take unnecessary time.

Is there any objection to the procedure which the chairman wishes to follow in this morning's hearing?

Hearing none, it is so ordered.

Does any member of the committee wish to make a statement before we proceed?

Mr. ENGLE. Mr. Chairman.

Mr. ASPINALL. The gentleman from California.

Mr. ENGLE. I would like to make a brief statement, saying that I concur in the remarks made by the chairman of the committee in connection with the résumé of the background of this matter, together with the interest we have in this hearing.

There has been a great deal of emphasis, since this program was initiated, on the importance of water throughout the United States. We in the western part of the United States, of course, have always been aware of that, but the President in his budget message this time had some very significant things to say regarding the problems of the water development. I suspect that a hundred years from now when people look back upon the vast scientific advances this generation of Americans have made, in all fields of science, including the atomic bomb and the hydrogen bomb, it will be a matter of some wonderment at that time why we were concerned with water to the extent we are when three-fourths of the world is covered with it and we somehow or other did not find a way, in spite of all of our scientific knowledge, to separate the salt from the water and utilize that water, why a great

portion of this continent is singularly concerned with the lack of water, and why the matter is of such importance at the present time and the President of the United States in his state of the union message should speak of it as one of our major problems.

Yet, we have not been able to utilize the vast quantities that surround the limited land there is of this world. So it seems to me that we have not been giving sufficient emphasis to this program.

There is a disposition in Government, in my opinion, to continue to research and experiment and to piddle around with practice programs instead of getting those programs into execution and in the pilot plant stage.

In directing the communication I did to our former colleague and present assistant Secretary of the Interior, Governor Aandahl, I wanted to get this program in focus before us, with the idea of really putting it into high gear and getting it off the ground out of the research stage, if it is possible to do it, and into the field of pilot plant operation so we can go forward with a real aggressiveness in solving the problem of separation of salt from water.

That is generally what I have in mind.

I hope, in addition to putting this program on a basis of high urgency, to suggest legislation which will permit the participation on a matching basis of those areas adjacent to the sea waters which surround our continent.

I can understand how a taxpayer in Minnesota or in any other of the internal States of the Union might not find the matter of separating salt from water one of the essential concerns to the people of that area, and say, "Well, why should the Federal Government carry all of this expense when people who are going to get the major benefit of it are those States of the Union lying adjacent to bodies of salt water?"

So I hope when we get this thing wound up and get it going on an urgency basis that we can get legislation which will enable States like California, Florida, Arizona, and Texas, who would profit materially from a successful program in the use of saline waters, to participate on a financial basis in carrying forward the research and the pilot-plant operations together with the Federal Government.

Mr. Chairman, I do have in mind those two objectives of this hearing; namely, to make this a program of greater urgency, and to make this a program of wider participation, especially by the States and areas that would directly benefit from the successful results of such research in pilot-plant operation.

Mr. ASPINALL. Does our former chairman, Dr. Miller, who has always given much of his time and effort to this program, wish to make a statement?

Dr. MILLER. Thank you, Mr. Aspinall.

I agree with your words and those of Mr. Engle. I think there is an old saying that necessity is the mother of invention, and we are finding areas in the world where water is mighty scarce and it is worth what it costs when you are thirsty.

I agree that the areas along the coast ought to have a greater interest in this saline water program and might well be expected to share some cost in return for the benefits they are going to receive.

Two years ago I was with a committee that went to Boston, Mass., and there were some processes there of separating salt from water or water from salt by a new process. I was intrigued by it.

I am happy to see we can go forward to new scientific discoveries to apply the knowledge we gain from technical and scientific experiments that are carried on.

After all, I think scientific investigation is nothing more than asking questions of nature and seeking an answer; we are doing that in this job.

I believe there are one or two pilot plants now being used in the program of trying to get salt out of water for irrigation purposes. The military is making rather wide use of this process.

I expect future generations will wonder what we were doing all the time when we were short of water and did not use some of that which was all around us. Undoubtedly new scientific approaches will find cheaper ways of making salt water potable.

I will listen with a great deal of interest to the progress that has been made and then hope, of course, we can get some practical application of the knowledge we do gain, because it is only by using that and putting it into practice that we are able to understand or know whether we are making some progress.

Thank you.

Mr. ASPINALL. At this time the Chair wishes to call to the witness table the Honorable Fred G. Aandahl, Assistant Secretary, Department of the Interior, for his statement. We are glad to welcome our former colleague, the gentleman from North Dakota, to this committee.

STATEMENT OF HON. FRED G. AANDAHL, ASSISTANT SECRETARY, DEPARTMENT OF THE INTERIOR

Mr. AANDAHL. Thank you, Mr. Chairman.

May I say that we in the Department of the Interior are appreciative of the opportunity of revealing the progress of the saline water program with the committee.

I have a brief statement I would like to read.

Mr. ASPINALL. You may proceed.

Mr. AANDAHL. The saline water conversion program has had the strong support of the entire Secretariat of the Department. It was made a part of my responsibilities as Assistant Secretary for Water and Power matters and I have taken an active interest in all of the work under the program. I am enthusiastic about the program and the prospects which it offers.

Of the natural resources of this earth essential to life and economic activity, water is among the most important. As with other resources, potable water is not distributed equally among peoples or nations. In some areas surpluses of this available resource exist, and in others severe shortages occur. It has become increasingly apparent in recent years that the supply of naturally fresh water in many parts of the world is insufficient for the needs. Rapidly expanding populations, rising standards of living, development of new water-consuming techniques, and expanding irrigation have increased the demand for fresh water.

Saline water conversion evidently is only one facet of the campaign against water shortage. Broadly the campaign will seek to conserve

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and make possible full utilization of our natural fresh water resources. It is a battle against waste. Flood water conservation, reduction of low-grade use of water, increased reuse, and correction of stream pollution all have a place; but long before the campaign proceeds very far saline water conversion must play an important part. Sea water at our shores represents an inexhaustible source and the Nation's inland brackish waters is another source of considerable importance.

The problem of salt water conversion is under systematic exploration by the Department of Interior and the work embraces scientific investigations in many fields, such as distillation, freezing, electrodialysis, solar distillation, and many others.

The study on demineralization has not been concentrated on any one process or plant because no single process is known which can economically demineralize sea and other salt waters for the requirements of both large and small consumers. It is anticipated that several different processes will eventually prove feasible and the choice of any one, will depend on such factors as its geographic location, type of water to be demineralized, intended use of converted water, and others.

Three different processes are now far enough advanced to justify the testing of experimental models at a seashore site. These are, a vapor compression still of new design, a solar distillation unit, and an evaporator scale-prevention test unit.

It is believed that the progress of the program has been consistent and correlated with the funds appropriated. The amendment to the Act of July 3, 1952, was enacted too late to permit any upward revision of the request for funds for fiscal year 1956. However, the Department immediately made a supplemental request for an additional $200,000 which the Congress appropriated May 19, 1956, some 10 months ago. This made a total of $600,000 for fiscal year 1956 in contrast to the $400,000 appropriated in 1954 and 1955.

Since this supplemental fund was limited to contract research which is mostly being carried out in fiscal year 1957, the request for this year was for $600,000 which would have made a total of about $800,000 for use this year.

However, only $550,000 of the $600,000 requested was appropriated and this reduction was all applied to administrative expenses. This curtailed the addition of a few personnel to the already small staff of the Office of Saline Water, urgently needed to accelerate the work. As a result the work has leveled off this year and stimulation of private activity and inspection of contract work which might have advanced the program was necessarily curtailed.

If the prospect for increased appropriation for fiscal year 1958, of $1,159,000, is completed the staff could be expanded sufficiently that the research and development work could be accelerated.

Immediately after the act was amended, I instructed the Director and the Office of Management Research to reexamine the structure of the Office of Saline Water and the research and development program to assure acceleration of the program. The work was reorganized and the Director of the Office of Saline Water will touch quite briefly on this improvement in his remarks. Unfortunately, because of limitation on administrative expenses, the reorganization is not complete.

I might say that the Office currently has 11 people employed. Six of them are scientists and five are clerical. Under the full reorganization we anticipate about 20 employees in the Office of Saline Water.

Mr. ASPINALL. May I just ask, are the six scientists the ones whose names I mentioned at the beginning of this hearing?

Mr. AANDAHL. Yes, four are. The other two whom you mentioned are contractors.

I have personally visited one of the developments at Cambridge, Mass., and inspected the No. 4 Badger-Hickman experimental model. Of particular interest to me was the possibility of developing smaller units of this type for use in individual homes and farms.

It is believed the committee will be interested in obtaining more specific information on two or three developments being investigated by different organizations. This information will be presented by the Director, Office of Saline Water.

You will also be pleased to learn that some of the investigations are out of the research phase and are now in the development stage. Continued exploratory research and development, however, will be necessary until one or more processes have been developed to the operating stage.

Mr. ASPINALL. Thank you very much, Secretary Aandahl.

The next witness is David S. Jenkins, Director of the Office of Saline Water, Department of the Interior.

STATEMENT OF DAVID S. JENKINS, DIRECTOR, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR

Mr. JENKINS. Mr. Chairman and members of the committee, we appreciate having this opportunity to discuss the saline water program again with this committee which has been so largely responsible for the program from the beginning. I was greatly concerned to learn that we may not have kept the committee completely informed of all of our activities, and as a result some of the members have expressed some disappointment in the progress as they understand it. I hope that this statement and the discussions today and tomorrow will bring more complete information to you.

I should like to say, we have just three ways of bringing information to you. One is the written word, and some of those reports are pretty long which busy people usually do not have time to read. We have the oral word, and we also have inspections of our work.

I should say that we have not arranged inspections for this committee or the other congressional committees in the past 2 years that we would like to have arranged, simply because we do not have the staff and personnel to do it. But we plan to do so in the near future, and I think when this committee sees some of the work that is underway the impression of lack of progress at least will not be as great as it is now.

At the time 2 years ago when the amendments to the saline water law were being considered, one of the members of this committee discussed informally with me whether large pilot plants should be authorized at that time.

As I recall, it was his suggestion at that time that, since the committee meets almost every day, it would be glad to hear from the Department at any time it felt that progress on certain processes had ad-

vanced to a point where special authorization for a large plant beyond the scope of the present authorization was needed.

While we believe and expect that it might be necessary to bring several projects to you for that purpose within the next 1 to 3 years, possibly including the Hickman still, the Badger cycle, a freezing cycle, and a solar still, there is doubt that any of these has reached the stage where we would be justified in doing so at this time.

I am glad that in the near future the present program will finally reach the rate of activity provided in the 1955 amendment so carefully considered by this committee. I say "finally" because, in the past 2 years, as Secretary Aandahl has pointed out, there has not been a full and unrestricted appropriation such as we now have some reason to hope for in the fiscal year 1958. There are still a number of administrative improvements which could be made, but even without them, we shall be able to move ahead more rapidly now.

One very eminent authority has said that the saline water program has the most difficult assignment in physical chemistry and engineering economics ever undertaken by the Federal Government; difficult not because of the complexity of the physical process involved, but because of the almost unsurmountable economic barriers. And during the past 5 years since that statement was made, those barriers have, of course, increased with inflation.

Many believe that it may be too much to expect final results in so short a time. Some sincerely believe that we shall never have fresh water from sea water at cost generally comparable with other sources.

Dr. MILLER. If I may ask a question there. How general is that feeling—50–50 or 9–10?

Mr. JENKINS. I wish I could take a poll, Dr. Miller, I do not know. But we do have quite a few scientists and engineers who do not believe we will have water at costs comparable with other sources.

Dr. MILLER. Of course, it is never going to be as cheap as going to a spring and carrying it away from where it runs out of the earth, or even pump it out of the ground. I did not mean that. But do scientific men generally feel it is not possible to complete the program for use, for instance, by irrigation or for large cities?

Mr. JENKINS. I think I can answer that question in this way: in the beginning of the program the skepticism was at a high pitch, and since we have made the progress that we have, one after another of the firms, engineers, and organizations who at first did not wish to cooperate with us, have come voluntarily now and are doing so.

Dr. MILLER. One more question. Is any work being done in the use of solar rays?

Mr. JENKINS. I am going to go into that.

In the beginning, because the existing conversion processes were very few and very expensive, and efforts to improve them over many years had produced little in the way of economics, it was necessary to consider every possible phenomenon and means of improving existing processes that might be used for this purpose.

The brochure "Demineralization of Saline Waters" was prepared describing briefly the existing and potential phenomena and processes on which developmental work might be undertaken to meet the problem.

Since the outline in the brochure forms the entire basis for the Saline Water Conversion Program, may we examine it step by step as a means of examining progress made in this activity.

Now may I refer to what is called exhibit A which is before you.

Mr. ASPINALL. Without objection, the exhibits with Mr. Jenkins statement will be made a part of the file.

(The exhibits will be found in the file of the committee.)

Mr. JENKINS. The table from that brochure, exhibit A, forms the entire basis of the present Saline Water Program. It was expected that some of the processes listed there would be eliminated through research, some would be advanced further, but later eliminated, and a few might reach the stage where field testing and pilot plants and even plants of commercial size might be justified.

It was fully expected that the field would narrow down, and all of this is now in progress. Yet, at the same time the field narrows down, it is of even greater importance, Mr. Chairman, that the flow of new ideas be stimulated to avoid finding ourselves depending completely on one or two processes that in the end might finally prove uneconomical.

Since this original list of processes form the basis of the entire program, and since we are here to review that program, I would like to run down briefly along that list and see where we stand.

Some have been eliminated. Then the technical witnesses will give more discussion of these processes that are advanced further.

First, under vaporization we have all of the distillation processes. They have one common obstacle, that of the formation of salt deposits within the distillation equipment. This scale, as it is called, must be either removed or the surfaces kept free of the deposits, otherwise the equipment does not operate efficiently.

Then referring to each of the processes under vaporization, the compression distillation is being studied and developed very actively, the principal progress being that of the Hickman still which is now reaching the stage where a plant can be taken to the seashore for long-term testing before going further.

The Department of the Interior undertook the sponsorship of the Badger-Hickman rotary vapor-compression distillation technique in 1954. Since that time much progress has been made in developing this wholly new technique in distillation and with promising results. Units of approximately 100 gpd, 1,000 gpd, and now 25,000 gpd were designed and constructed.

Considerable research work on the two smaller experimental Badger-Hickman rotary stills, including extended tests on imported sea water, were completed during 1955 and 1956. The 25,000 gpd unit has just been completed and a series of experimental tests has been initiated.

As a result of the progress to date, heat transfer rates have been achieved and satisfactorily sustained which are 5 to 7 times higher than are achieved with existing similar commercial equipments. After the shakedown tests at the contractor's plant which are scheduled to run through this spring, it is planned to take the unit to a seashore site for extended tests on sea water.

Multiple-effect evaporation is being developed principally in connection with the W. L. Badger cycle. That work is getting underway, and Mr. Badger will discuss the two cycles which he has proposed during these hearings.

With the cooperation of the Whiting Corp. of Harvey, Ill., plans for establishing an experimental test facility for evaporation studies were completed. Experiments with such a plant are expected to determine if the multiple-effect cycles previously proposed by W. L. Badger can be operated essentially free of scale deposition on the heat transfer surfaces. The facility will include a modified long-tube vertical evaporator upon which the initial tests will be run, as well as two forced-circulation evaporators to be used for simulating the various multiple-effects in preparing the feed for the test evaporator. This provides a flexible arrangement.

Initial test procedures for both scale and corrosion studies are incorporated in the plant. In the absence of a needed experimental or test station adjacent to sea water, the Office of Saline Water has obtained permission to utilize facilities of the International Nickel Co. laboratory at Harbor Island, N. C., and a part of the Navy (Bureau of Ships) facilities also there for this particular extended test project.

With the third, flash evaporation, work is underway now at the Griscom-Russell Co. at Massillon, Ohio. The work is combined with No. 9, commonly referred to as "temperature differences" or "low temperature differences" and it is expected that design of a low temperature difference plant will be prepared within the next 9 months. If that design shows that economic feasibility may be attained, further work will be necessary.

The current project at the Griscom-Russell Co. calls for research on and analysis of low-temperature flash evaporation processes when utilizing low thermal differences. A study is being made of means for simplifying existing distillation equipment to produce drinking water of 500 parts per million from 35,000 parts per million sea water. In order to determine the economic feasibility of this process preliminary designs are being developed for using this single-effect flash technique in 100,000 gallons-per-day and 10 million gallons-per-day capacities.

With the fourth, distillation processes flash type multiple-effect evaporation, no work is being carried on by the saline water program at this time. But some should be carried on, and we simply have not had funds and personnel to go into that at this time. Certainly some research and development work is in order. Private industry is supplying these evaporators for shipboard and other established uses.

With the fifth, combinations of compression distillation and multiple-effect evaporation, this too is being studied under the W. L. Badger cycles.

With No. 6, critical pressure devices—that is one of the most attractive processes that we have. It was discussed before this committee by Dr. Laserson.

This system was originally proposed by the Swedish scientist, Baltzar von Platen. The program has developed it in contract work at White Plains, N. Y., until one obstacle was reached which has not been overcome so far—the formation of scale within this high-temperature equipment. The work has been discontinued until that obstacle can be overcome. It is a very attractive process economically but until the scale can be prevented, no further work seems justified.

With No. 7, superheated steam, one attractive cycle has been suggested and some work should be conducted. None has been carried on so far.

With No. 8, underwater combustion, this is considered as a means to an end only and is not a process.

With crystallization, the freezing of water presents a very attractive salt-water conversion process. As will be discussed by members of the staff, two freezing processes are now under intensive development and it is believed that either may ultimately be as economical as any process under development.

Mr. ASPINALL. Is the committee to understand that when salt water freezes the ice then becomes free of salt?

Mr. JENKINS. Yes, sir, that is essentially correct.

Dr. MILLER. Is that distilled water?

Mr. JENKINS. That is relatively pure water. Some of the salt is entrapped in the interstices between the crystals. Depending upon the rate of freezing, more or less of the salt will be occluded to the crystal.

Although several organizations and individuals have expressed great interest in the adaptation of a freezing technique to sea water conversion, there was little work conducted outside of the Department of the Interior's program, in this field.

The Italians and Germans and 1 or 2 organizations in this country including the United States Navy had performed limited experiments in order to determine some of the fundamentals of the process. However, most of this work has been terminated. Since that time the saline water program has vigorously undertaken studies in this field in order more fully to exploit this process.

Existing commercial freezing equipments were studied at the University of Washington. It was determined that with freezing cycles utilizing current commercial equipment, cost of fresh water will at best be no lower than is realized with the present commercial distillation equipment.

However, improved freezing and brine separation cycles may be capable of realizing greatly reduced costs, competing perhaps with some of the best crystallization processes under development.

Therefore, current research is actively pursuing the development of new cycles such as with freeze-evaporation at Carrier Corp. and zone freezing at Battelle Memorial Institute.

Concurrently, basic investigations are continuing in the field of ice crystal study and brine ice separation by Applied Science Laboratories in Pennsylvania. It is anticipated that considerable progress will be made on this process in this field during the next fiscal year.

It was believed that zone-purification (zone freezing) might alleviate the phenomena of entrapment and adsorption of brine on the ice crystallitea, customary in any freezing process, so an exploratory research investigation was initiated at Battelle Memorial Institute.

Results to date look fairly encouraging and the technical feasibility of the process has been established. With salt solutions containing 20,000 to 30,000 parts per million, 97.5 percent of the salt can be removed in a single directional freeze.

The work is continuing and soon a firm evaluation of the process from an engineering viewpoint will be made.

With regard to crystallization of salts we see no immediate practical way of utilizing this principle.

The same can be said of sublimation, adsorption, and diffusion effects although with all of these, should a sound scientific proposal be brought to our attention, we would certainly consider it on its merits.

Some work has been carried out on the program of ultrasonics and at present it is believed that this work is sufficient to conclude that salt water is not susceptible of separation by the application of ultrasonics.

What we are doing here is trying to find some solution to this rather difficult problem. You just do not go out and build a plant until you know what you are going to put in it.

Mr. ASPINALL. May I say, in return, that before this committee 2 years ago, some of us were led to believe we would proceed just a little bit faster than we have, and we have seen statements which appeared to hold hopes which some of us are now beginning to feel are not near what we thought they were; and we wish to protect the public in its feeling about success, immediate success, or ultimate success, or maybe the opposite, failure of the program.

Mr. JENKINS. Mr. Chairman, I am in complete sympathy with that viewpoint.

Mr. ASPINALL. That is the reason for the hearings.

Mr. JENKINS. If the statements were overall optimistic, it was the natural optimism, probably of the scientist and inventor, and we feel that is a good thing. We have tried to temper those reports that have been sent to us, and in almost every case, I believe, there may be 1 exception or 2, we have assigned the responsibility for that optimism to the people who were working in the field. It might be borne in mind that at that time we had only 3 men in my office, 2 besides myself, and we could not check on every estimate that was made. But I will go into that a little further in the testimony, if I may.

With osmosis, work has been carried on with the University of California on molecular oil films for the past 3 years and although responsibility for that activity has now been taken over by the university under its program, it is a possible process and may develop into one which is economical.

With biological membranes, work is now just getting underway. No proposals were received until recently, not withstanding the fact that the subject of separation of salt from water by animal tissues has received considerable study in the past. It is well known that this type of separation is very effective and that such tissues perform more efficiently than any machine made by man.

A third osmosis process not originally included in the outline was proposed by the University of Florida. This is referred to as reverse osmosis. This process is being investigated at the University of Florida and to date the results look fairly promising. By using cellulose acetate as the semipermeable membrane 95 to 97 percent of the salts in sea water have been removed in one pass. A small fundamental research investigation has just been completed which resulted in a hypothesis explaining how and why membranes behave as semipermeable membranes under pressure.

The flow rate and durability of these membranes must be improved before the process can be considered practical. It is now believed that by application of the recent data and hypothesis it may be possible to synthesize semipermeable membranes with a greatly increased flow rate and durability. If this is accomplished, it will be followed immediately by engineering designs of a pressure cell and the testing of a laboratory model on sea or other saline waters.

Use of immiscible liquids. The solvent extraction method in which water is soluble but salt is insoluble, work has been under study at the Texas A. & M. Research Foundation for about 3 years.

These results were not considered very attractive until last year when the final report was received and it showed considerable economic promise. The work is being continued this year with one man just to keep the project active because of the shortage of funds and it is expected that it will be placed back in full development beginning in fiscal year 1958.

Then moving into the chemical processes, ion-exchange has never been considered as very important in the saline water conversion program as it is probably economical only for treating very low salinity waters, usually those considered as fresh water, for attaining very high purities.

However, the University of California is carrying on research endeavoring to develop a means by which ion-exchange materials may be re-generated by the use of heat. If successful, that work may broaden the use of direct ion-exchange.

With regard to hydration and precipitation, these do not appear attractive but have not been abandoned altogether.

Under the electrical processes those relating to electro-ion-migration follow three groups.

First, straight electrolysis is not considered as economical and it has been eliminated from the list, at least for the present.

With perm-selective membranes referred to as electrodialysis or the ionic process, we have here a very attractive process for treatment of brackish waters.

Dr. Miller and other members of the committee have seen that process under development at Boston.

It will be discussed at considerable length later in these hearings. Work was carried on through the saline water conversion program by the only firm in the United States actively engaged in this development. That firm has now placed its units on the commercial market. Their efficiency is somewhat less than had originally been calculated. No direct work with that firm is underway at present. Field tests of that equipment have been carried out over a period of 2 years and the equipment is now in the laboratories of the Bureau of Reclamation undergoing prolonged durability tests.

Meanwhile, several other firms have become interested in this process, including the Central Technical Institute of the Netherlands. Work is underway through the saline water conversion program at the Bureau of Standards, Brooklyn Polytechnic Institute, and the Bureau of Reclamation on improvement of membranes for this purpose.

Members of this committee will recall that after laboratory tests had showed considerable promise, equipment was taken to Arizona and South Dakota where it was operated on well water.

Dr. MILLER. How many universities are participating in your research program?

Mr. JENKINS. At present we have 21 research and development contracts, 9 of which are with universities. Two years ago we had 30 in all. The field is narrowing down a little. The reason for that is we are

moving into development of larger pieces of equipment, and the number of ideas has diminished.

Dr. MILLER. Have you any pilot plants operating now in Arizona and South Dakota?

Mr. JENKINS. I was advised today by long-distance telephone that the Hickman plant was making water yesterday for the first time in their shop at Cambridge. It will be moved into the field after the original tests have been made.

The field experience in Arizona and South Dakota disclosed many problems and we now have the final results of those tests, which are somewhat disappointing.

The costs are higher than expected, largely because of one factor: The capital investment in equipment, as charged by the only firm in this country producing this equipment, is so high that if amortized at 4 percent interest, the cost of the water is much greater than had been estimated from laboratory results.

The selling price of equipment like that tested in the field is $63,000. This cost, together with that of the membrane replacement amounts to nearly 80 percent of the total cost of the water. If extended to a much larger installation, if one were built, and one has not been built, it is estimated that these costs would be about 50 percent of the total cost.

This problem of equipment cost arises from the necessity of calculating on the basis of custom-built equipment. In fact, that is the principal reason for the high cost of most conversion processes. Nearly every piece of conversion equipment built today is custom- or job-shop-built. Mass production methods cannot be used until the market increases, and the market cannot increase until the cost of the equipment is reduced. This paradox is not new; it exists with many new products. There is a problem in risk capital and the problem is receiving much study by the firms involved.

Meanwhile, a similar process is being developed in Holland and although the greatest possible effort was expended in an endeaver to participate in that International Cooperative Research, questions raised regarding the desirability of the cooperation on foreign research made it necessary to obtain special legislation for that purpose. By the time the amendatory legislation was enacted in 1955, the International Cooperative Group in Europe had received sufficient contributions from other countries and our late offer to cooperate was declined. This is very regrettable in view of the fact that the total costs of water by the process may be much less than that produced by other similar processes.

Although private firms in the United States will probably be licensed and the Dutch equipment sold in the United States eventually, the advantage (if it is an advantage) of free public patents offered by the Dutch had the Department of the Interior participated, will not be realized.

Fortunately, the technical group in the Netherlands is cooperating wholeheartedly with the Office of Saline Water, exchanging information and even supplying us with some of the membranes and other equipment for our test use in Denver. This has come about as a result of our personal contacts.

With the third electro-gravitational process known as electrical gravity, methods as well as the following five processes, streaming

potential, electrostatic effects, and electromagnetic effects, no feasible means of putting these principles to practical use for converting salt water to fresh water has been proposed. It is doubtful if they will be found practical for this purpose.

With ultra high-frequency currents, attempts have been made to demonstrate that salt water can be separated by this means, but these have been unsuccessful until processes are developed by others demonstrating this feasibility. It is not anticipated that further work will be carried out in this field.

Osmionic—an entirely new process known as osmionic has been developed under the saline water conversion program by Dr. George W. Murphy, formerly of New York University and now of the University of Oklahoma. This is a very attractive process utilizing membrances and a differential in salt concentration as the driving force in place of an electrical current. It will be discussed by one of the staff members in more detail. It is now under engineering development in the Southern Research Institute in Birmingham, Ala., and, based upon the results so far, we can predict that unless some unforeseen obstacle arises, this process should emerge as a practical process at a relatively reasonable cost.

The simplest unit (unit cell) consists of 2 cation- and 2 anion-selective membranes forming a 3-compartment cell. A small laboratory unit has been fabricated and operated successfully.

A practical unit capable of demineralizing 2,400 gallons per day is now under construction at Southern Research Institute. The individual membrane packs or unit cells are amenable to mass production and it is anticipated that the proposed practical unit can be fabricated at reasonable cost and operated with a minimum of downtime.

Solar heat provides one means of reducing energy costs and, therefore, much work has been carried on in solar distillation. Although the first efforts indicated that work was not pointing to economical feasibility more recent developments are much more encouraging. That work is to be discussed during these hearings by Dr. George Lof, eminent authority in solar energy who has for 4 years been working in the solar distillation field as just one of his solar interests. Others who have been working on these processes include Dr. Maria Telkes of New York University, and Bjorksten Research Laboratories, and the University of California.

Cooperation is maintained with the European working party on solar distillation and one of the improvements made under that European cooperative work in north Africa has been adapted in the experimental still to be installed at San Diego.

Recently the firm of E. I. du Pont de Nemours & Co., Inc., has become interested in solar distillation and has prepared a design utilizing a plastic film manufactured by that company which is reported by the firm to have promise of producing fresh water from salt water at a relatively low cost.

A cooperative agreement with Du Pont has been entered into and it is expected that some of the Du Pont stills will be installed at San Diego, Calif., adjacent to a still designed by Dr. Lof which will be constructed there within the next few weeks.

Combinations of saline water conversion cycles with nuclear power generation plants have been suggested as another means of reducing energy costs. But the cost of electrical power or heat from nuclear

energy will have to become competitive with that from other energy sources before this may be realized.

However, there may be other ways of economically combining these processes such as in certain operating advantages that might be gained in utilizing the energy from the reactor during off-peak load periods, if the reactor plant is not primarily used for base load only. Studies of the possibilities of multipurpose advantages have been under consideration for some time by the Office of Saline Water and we are currently considering the possibility of a jointly sponsored project with the Atomic Energy Commission in this field.

Thus, as a result of this research and development so far the activity has narrowed to about 7 major fields, rather than the 35 or 40 that we have just reviewed. It may be that, if none of these undertakings is successful, the people whom Dr. Miller asked about might be proved correct. We may not have fresh water from sea water in abundance at extremely low cost. But some of these developments do look good.

These are shown on the 2-year plan which is revised as frequently as necessary to keep abreast of progress. The present 2-year program is shown as exhibit B.

First, the development of the rotary stills that we have discussed.

Then other distillation, including that of Mr. Badger, and solar distillation.

Then the membrane processes.

Then the freezing processes.

Then other exploratory research and necessary surveys.

Then last we have need, as we reported, for some kind of a test facility.

We use this 2-year plan, as we call it, to keep our work current. As I said, the plan is changed as frequently as possible. This version is dated January 1, 1957. We also use it for discussion of appropriations.

Now I should like to say just a few words about the organization that is carrying out the work. As Secretary Aandahl mentioned, the entire activity was reorganized, and exhibit C, which is before you, is an organization chart.

I do not want to bore the committee with organization charts—the members have seen many of them—but this one is a little different, in that we have between 200 and 400 people working full time and part time on this activity, and at present those shown in the heavy black boxes in the center total 11 in the Government.

Now that reorganization was necessary to divide the work into the research activities and the engineering and development activity. I am very sorry that the impression has become rather universal that our program is strictly a research program; it definitely is not.

The research projects are small. They may be for only three or five or ten thousand dollars, but the heavy work is now in the branch of engineering.

Also, as you will recall, Mr. Chairman, a part of our requirement was to encourage and stimulate private activity in this field, and that is where the Branch of Coordination comes in.

For example, in the Branch of Research, we have about 30 scientists working under contract and about 60 nontechnical or semitechnical personnel, totaling nearly 100 people working there. Likewise, over 100 are working in engineering and development. A similar number

are engaged among these other cooperating groups working with the branch coordination. We also have some 50 or more of the country's eminent scientists and engineers serving as consultants, and I am pleased to say that they have time and again reviewed the program. We depend upon them to evaluate each proposal, whether it is engineering or research, before we go into it.

This proposal of Mr. Badger's was evaluated by eight, I believe it was, of these people, including persons within the Government. This is done partly because we have what might be looked upon by some, and has been referred to by some, as a "giveaway program," contracting with outside firms. We want to be sure that we do not just give away money.

Mr. ASPINALL. At that point, Mr. Jenkins, referring to chart B, from which one of these funds do you pay these specialists that will be before the committee? Does that come from "Administration and coordination" or does that come from the funds you have set forth in 1, 2, 3, 4, 5, 6 and 7?

Mr. JENKINS. Four of the gentlemen who will appear are on my staff and they are paid from administration funds.

Dr. Lof is a contractor. He has a development contract. Mr. Badger has a development contract. They are paid from their contract funds.

Mr. ASPINALL. Now these consultants to whom you make reference, are they paid from the administration and coordination funds?

Mr. JENKINS. They are given a small research contract. They are paid from contract funds, with the exception of 4 who are on a WAE basis, whom we call on, and those 4 are paid on administrative funds.

Mr. ASPINALL. What is the number of personnel then that comes under No. 8, "Administration and coordination"?

Mr. JENKINS. The number of people?

Mr. ASPINALL. Yes.

Mr. JENKINS. Under No. 8?

Mr. ASPINALL. That is right.

Mr. JENKINS. That is 11 people at present, plus 4 WAE consultants.

Mr. ASPINALL. Plus what?

Mr. JENKINS. WAE consultants.

Mr. ASPINALL. What does "WAE" mean?

Mr. JENKINS. When actually employed.

Mr. ASPINALL. What is your rate of employment for such personnel?

Mr. JENKINS. We use those people about three or four times per year on an average.

Mr. ASPINALL. How much do you pay them per day?

Mr. JENKINS. $50 per day, usually. I think our total expenditure for that group has been less than a thousand dollars a year.

Mr. ASPINALL. For each individual?

Mr. JENKINS. Altogether.

Mr. ASPINALL. In other words, what you are saying is this: that for fiscal 1957, you had an appropriation of approximately $115,000 appropriated for 11 people. Is that right?

Mr. JENKINS. Yes, sir.

Mr. ASPINALL. All right, you may proceed.

Mr. JENKINS. May I add there that we requested $165,000 in order to have enough people to get the program accelerated.

Mr. ASPINALL. As I understand, that would have taken care of the executive assistant and secretary and so forth, positions which are now vacant. Is that correct?

Mr. JENKINS. Yes; those in several scientific positions. We have no chief of coordination. Dr. Gillam has no assistant. And we also need two field test engineers.

I made an analysis of one of the branches last year in June to determine just what its needs were. In order that this committee may understand those needs, I should like to quote a short passage from this report that was prepared at that time:

> As of June 1956 the Branch of Research is supervising coordination of a total of 10 contracts. This work involves keeping abreast of the monthly or bimonthly technical progress reports required of each contractor, careful examination of their results, suggesting changes in procedure of scope of each research investigation, assisting in the direction of these research investigations, correlating the results with all other investigations in this field, and ascertaining that all provisions of the contract are fulfilled.
>
> As of that time, that Branch had 17 current new proposals to be evaluated and involved a technical analysis of each proposal by the Branch Chief, the selection of qualified consultants to evaluate each proposal, drawing up consultant contracts and correspondence with each consultant. Upon receipt of the evaluations from each consultant they must be critically reviewed by the Branch Chief, who then ascertains the feasibility and need for specific research contracts, and makes such recommendations to the Director.
>
> Finally, following all this—and in acordance with the requirements of the Department—documentation of all of these negotiations must be kept and made and all of that requires considerable time.
>
> In addition, there is stimulation of research by correspondence and then pyramided on those activities are the day-to-day duties, including voluminous correspondence to be answered, much of which requires technical evaluation and some library research, preparation of budgets, monthly, quarterly, and annual reports.

I should like to say a few words as to the cost estimates, which I feel has been made clear maybe one of the understandable disappointments which some of the members have expressed.

During the early years of the program, it was necessary to depend very largely upon the few industrial firms that were manufacturing distillation equipment for estimates of costs of water that was being produced in existing processes, and that which might be produced if larger plants were to be built. It was necessary to quote the sources and to make it clear that the costs of water were computed by others, and this was done, with adequate qualification I believe.

By the summer of 1955, it had become clear that some central standardization of cost estimates must be undertaken. Lack of uniformity was by then beginning to show up in almost every estimate of cost, and in many development proposals. Such estimates were being made on a different basis by each individual. One would use one set of assumptions, another an entirely different set. Some amortized capital costs on the basis of 7 years, some at 15 years, and some at 30 years. Some simply failed to consider it at all.

By the fall of 1955, the preparation was begun on a standardized cost estimating procedure for use of the Office of Saline Water only, in which all real costs would be included, and based upon the best industrial experience available.

With the cooperation and help of some 9 experienced private engineering organizations and consultants, the Bureaus of Reclamation, Mines, and Geological Survey, and the staff of the Office of Saline

Water, a cost estimating procedure was prepared. Some of the private firms which assisted have had actual experience in installing distillation equipment. The procedures include all real costs. There are no nonreimbursable costs. Even such matters as taxes and land costs are included.

Equipment is amortized over a period of 20 years at 4 percent and the cost of power is assumed at 7 or 5 mills. This is all done with the expressed intention that this method provides a comparison between various processes. It is realistic and conforms to practice used in industry. It is not final or infallible, and retains the one inherent weakness of having to depend on the contractor's estimates of cost of individual items of equipment, amount of power, labor and operation charges. This procedure is referred to in exhibit D.

I should like to discuss very briefly this exhibit D, which is the cost estimating procedure.

On the first page, the foreward, you will note the names of the firms which helped prepare this. Then at the bottom of that page we state that:

> It is emphasized that this estimating procedure is for use in obtaining a preliminary estimate of costs. When sufficient engineering data become available for a particular process, the estimate of costs should be refined by using actual costs, instead of using percentage factors.

I believe that is one of the best answers to the question of why do the costs seem lower at one time and higher at another.

As a result of applying this standardized yardstick to the many and varied computations that have been submitted by our contractors and others, we now have cost estimates of future large installations on the basis of this procedure which in general are considerably higher than before.

I have gone into some detail about this because we feel that the present procedure in estimating costs is realistic and certainly not overly conservative, but I feel that the results of using it may be the source of some disappointment that has been expressed in cost of water. The apparent increases in cost do not reflect lack of urgency, diligence, or progress.

Exhibit E is a table showing the estimated projected costs of a few processes on which we have sufficient laboratory and other data that we dare to make such a projection into the future. The table shows the estimated costs made by contractors from their best available information, and similar estimates made by this standardized cost estimating procedure.

Although not all of the apparent increases are due to this cost estimating procedure, this illustrates what we have, and I would like to go through just two of these examples.

Mr. ASPINALL. Off the record.

(Discussion off the record.)

Mr. ASPINALL. Back on the record. You may proceed, Mr. Jenkins.

Mr. JENKINS. In the first example at the top of the page, this has to do with electric drive vapor compression equipment which has been in use for many years and was in use when this program was initiated. The hearings before the joint Senate committee contained a very fine estimate by one of the major firms producing this type of

equipment, and the costs were computed on the basis of the best information they had; but it was on the basis of a large plant, if one should ever be built, and none had been built at that time.

The estimated cost by their procedure was $1.12 a thousand gallons.

Subsequently, they have built a plant and it has been put in use on Gibralter. Using the actual 1955 f. o. b. costs, together with our standard estimating procedure, the cost comes out at $1.85 a thousand gallons, and from what information we have that seems to be even lower than the actual cost of the water.

Now the last one at the bottom of the page, the Ionics process.

In 1954, a cost estimate made by the company on the basis of a very small unit, hardly larger than this picture of water (indicating) came out to be 6 cents a thousand gallons for treating water of 4,000 parts.

Mr. ASPINALL. The bells have rung, and that takes care of the situation for today.

Mr. Secretary, can you be back with us tomorrow?

Mr. AANDAHL. Yes.

Mr. ASPINALL. We would appreciate it if you would come back because we have two or three questions to direct to you.

We shall recess this hearing until 10 o'clock tomorrow morning.

(Whereupon, at 11:10 a. m., the subcommittee adjourned, to reconvene at 10 a. m., Friday, March 8, 1957.)

SALINE WATER RESEARCH PROGRAM

FRIDAY, MARCH 8, 1957

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON IRRIGATION AND RECLAMATION OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS.
Washington, D. C.

The subcommittee met, pursuant to recess, at 10:15 a. m. in the committee room, New House Office Building, the Honorable Wayne N. Aspinall, chairman of the subcommittee, presiding.

Mr. ASPINALL. The Subcommittee on Irrigation and Reclamation of the House Committee on Interior and Insular Affairs will now be in session for the further taking of testimony and questioning of witnesses on the saline and brackish water program.

Yesterday when we were forced to adjourn the committee, we had at the witness table Assistant Secretary Aandahl and Director Jenkins. Director Jenkins was finishing the oral presentation of his testimony.

Will you two gentlemen take seats at the witness table?

Mr. Jenkins had gotten down to the last part of his formal statement.

Mr. ASPINALL. You may proceed.

STATEMENTS OF HON. FRED AANDAHL, ASSISTANT SECRETARY, DEPARTMENT OF THE INTERIOR; AND DAVID S. JENKINS, DIRECTOR, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR—Resumed

Mr. JENKINS. Mr. Chairman, if I may request a slight change in the program, due to the loss of 1 hour yesterday, I think with your permission we should like to call, following this conclusion, one technical witness from my office and 2 technical witnesses from outside Washington. And then, if, after your questioning, there is still time, I would like to call the other two technical witnesses from my office.

Mr. ASPINALL. Unless there is objection, that may be done.

Mr. JENKINS. I also want to say that in closing yesterday I had fully intended to distribute copies of the current issue of Scientific American magazine, in which that magazine has kindly given us the lead position in an article which it was my privilege to prepare, which describes in general this field of activity.

I want to say publicly that in the editing of that article, somehow the name of Mr. W. L. Badger was dropped out. I regret that very much.

Mr. ASPINALL. Unless there is an objection, the article will be taken from the magazine and made a part of the file. With no objection it is so ordered.

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Mr. JENKINS. In concluding, Mr. Chairman, on the subject of different cost estimates that we were discussing on yesterday, the exhibit E that we were discussing showed the original cost estimate on the ionic process by their methods, with what little information they had at the time, at 6 cents a thousand gallons for treating brackish water containing 4,000 parts per million of salt. Later, with more information, by their methods, the cost was computed at 22 cents a thousand gallons if large plants were to be built; and finally, by our standard cost estimating procedure, the cost comes out to be 41 cents a thousand gallons.

Now, there is a very good reason for that last. If we may refer to exhibit F for just a moment, we will find those cost estimates, and we will find that the plant investment in the first group of estimates across the page is what causes this final estimate to be very high. The cost of that equipment as produced by the only producer now in the United States is estimated at $63,000. The replacement of membranes and the plant investment together amount to about $1 out of the total cost of $1.30. And in the extension to a very large plant, if one were built, a similar but not as great disparity exists. There the plant investment is about 50 percent of the total cost of 40 cents a thousand gallons.

Now, that brings up the very important question of custom built equipment. In so much of the equipment that is built today, the market has not increased, has not developed, sufficiently that mass production methods can be used. Equipment is built on a custom-built basis or what is called the job shop basis, but mass production methods cannot be used until the market increases; and the market cannot increase until the cost of the equipment is reduced.

Now, that paradox is not new. It exists with many new developments. I can think of color television as one. But it does represent a major problem in risk capital that is receiving a great deal of study by the firms themselves, who are confronted with this problem. It is expected that eventually these costs will be reduced greatly when that investment cost is reduced.

Meanwhile I should say that there is being developed in Holland a similar process to this ionic process, which we have great reason to believe will produce water at much lower cost than is possible today. The Department was invited to cooperate with that work in Holland. It is very regrettable that we were unable to do so. The reason we were unable to do so is that questions were raised which made it necessary to seek further legislation, which this committee passed, specifically enabling us to cooperate abroad on such activities. But by that time, the Dutch had all of the contributions they needed from other nations and declined our offer. We are cooperating with them, however, in exchanging information, and they have sent us samples of their equipment, which we are testing, in Denver.

The personal contacts that we have made have been responsible for the fine cooperation that we have. However, we will not have, Mr. Chairman, the public patents on that Dutch process that we would have had if we had been free to cooperate financially in the beginning.

Now before asking the others to discuss the several process developments, I should like to point out that in all of the distillation processes, the formation of salt deposits within the equipment, known as "scale formation," presents the most serious obstacle to low-cost distillation.

Whenever sea water or many brackish waters boil at temperatures above about 150° F., the salt deposition forms in hard or soft scale which very seriously retards heat transfer, and total efficiency. In the distillation processes to be discussed this matter of economical scale prevention at economical costs is paramount. In fact, it is of such seriousness that we do not feel at present that any process on which we are working can be considered ready for the large-scale pilot or commercial size plant until operation on a scale-free basis is assured by actual rigorous laboratory tests. Although the Hickman still operates at high efficiency without scale formation, it does so only at temperatures up to about 150° F. If it can be made to operate scale-free at atmospheric pressure and temperatures of 212° F., the production of water will increase tremendously and the resulting costs per gallon will be decreased correspondingly.

Likewise, with the cycle devised by W. L. Badger, scale prevention is absolutely necessary before the cycle can operate as designed. Therefore, a primary objective of the work in distillation is now the economical prevention of scale formation. Such scale can, of course, be prevented by certain treatments of the water at present, but in general the cost of some of those developed so far is greater even than the total costs of the water we are seeking in this program. During the coming year a concerted attack on scale prevention is planned, both that in the W. L. Badger cycle and for other cycles. Expansion of the cooperation with the British in solving this problem, which has already begun informally, is being considered.

Now, that concludes my statement, except for just summing up what I have said, if I may for one minute.

If I may be permitted this one remark: one eminent scientist as I recall stated quite some time ago that the time between the conception of an idea for a major technical development affecting a broad segment of the population and full scale commercial acceptance and use of that development is about 20 to 40 years. The automobile was invented in about 1890, and it was not until the 1920's that extensive commercial use of automobile and truck transportation was underway.

The Wright Brothers flew their first airplane in 1902, and it was about 1942 when air commerce became general.

The original theories for atomic energy were advanced in the 1930's, and it may be safe to guess that by 1960 or 1970 we may have general use of atomic energy.

Therefore, in the five years that we have been working, with $2 million spent so far, or about one eight-thousandth of the amount that has been spent on atomic energy which I understand is about $16 billion, we feel that we have made some progress. That progress can be summed up as follows:

The field of processes has been reduced from 19 general groups to 6.

No. 2, four processes have been advanced to the pilot plant stage.

No. 3, there have been several processes which have been advanced to the engineering stage.

No. 4, there have been developed three wholly new principles to separate salt water, all of which are expected to reach the engineering stage in 1 or 2 years.

No. 5, work has been initiated on two wholly new principles.

No. 6, we are now initiating and planning to begin in July active exploration, possibly in cooperation with the AEC, of combinations of atomic energy and salt water conversion.

And No. 7, there has been stimulated a very significant number of private investigations by private firms.

No. 8, we are cooperating with a large number of foreign countries; and I believe there has been a great deal of good will generated.

Mr. ASPINALL. Now, Mr. Jenkins, in line with that last statement that you made, as chairman of this committee I do not wish to minimize the importance of the results which you have accomplished up to the present time. I for one am not critical of the progress of the program. I may be critical of some of the statements that have been released, and so forth, simply because I think that they are misleading.

I wish to get back to your exhibit E, where you set forth the estimated cost of converted water per thousand gallons as you have determined it to be over the past several years.

Now, as to your vapor compression distillation method, the statement was made in 1951 that it cost $1.12 per thousand gallons. In 1955, that cost had been raised to $1.85 per thousand gallons.

Now, in acre-feet cost, that amounts to $370 in 1951 and $610 in 1955.

The W. L. Badger multiple-effect evaporation process in 1956 was 33 cents, as estimated by Mr. Badger, which was $110 per acre-foot and by 1956 it had advanced to 39 cents, which is $130 per acre-foot by the standard cost estimating procedure.

As for the ionic method in 1954 it is 6 cents, which would be $20, but in 1955 it had gone to 22 cents, which would be $73. And in 1956 it had been raised to 41 cents. That would be $135 per acre-foot.

Now, I think that you will agree with me that as we figure these costs and we release statements concerning them, the public can pretty well figure what the cost of water is, even for domestic and municipal purposes, let alone for agricultural purposes.

The facts of the case are that we do not have any program at the present time which would lead any sane person to think that the opportunity of making potable water or usable water from saline or brackish waters for irrigation purposes is anywhere near in the foreseeable future; is that not right?

Mr. JENKINS. From brackish water? Or sea water?

Mr. ASPINALL. From either one.

Mr. JENKINS. No, from brackish water, depending upon the brackishness of the water, as we have stated in all of our statements, if further research is successful, we certainly believe that we will have processes that can use some waters for municipal and industrial and some irrigation purposes.

Mr. ASPINALL. Tomorrow, 1960, or 1970, or 1980?

Mr. JENKINS. Mr. Chairman, that is something that no one can tell. That is the thing that we are asked over and over again by members of the press and others. I endeavored to explain yesterday that we have, in all cases, made a rather thorough explanation of our estimates. But I do want to say that those statements have been taken, because of the need for condensing space, I expect, out of context in a number of cases.

Now, I have an example right here before us.

Mr. ASPINALL. Let me give you the examples before you give them to me, just so that I can get your understanding.

Now, with reference to brackish waters you say that it is perhaps feasible some time in the future. But you do not think that statement is true so far as sea water conversion is concerned, do you?

Mr. JENKINS. Yes, sir.

Mr. ASPINALL. That you can change sea water——

Mr. JENKINS. I beg your pardon. From sea water into irrigation water?

Mr. ASPINALL. Yes.

Mr. JENKINS. It would depend entirely upon the cost that can be afforded by the irrigation user.

Mr. ASPINALL. Now, if these figures that you have given to us figure out at the lowest possible level in 1956 at $130 per acre-foot, you are not insinuating that anybody is going to be able to use that kind of water for irrigation, are you?

Mr. JENKINS. Congressman Aspinall, that one figure at the bottom of the page concerns only the ionic process of Ionics, Inc.

Mr. ASPINALL. I did not choose the one that had to do with the Ionics process. I chose the lowest one, which had to do with the vapor compression and multiple-effect process of W. L. Badger.

Mr. JENKINS. We have not, and I am quite sure Mr. Badger, when he testifies, will also agree with that we have not, considered his process in connection with irrigation. We have not considered it in regard to any special use.

Mr. ASPINALL. Well now, let me refer you to an article which is entitled "For Water Shortage, Relief From the Sea, Special Report," and a statement which you are supposed to have made:

> "We have developed some very startling new facts since then"—says David S. Jenkins, head of the Office of Saline Water.

And then we follow on through. And I admit that I am taking these out of context perhaps. In fact, this is not what you are supposed to have said. This is the author.

> In fact, some Government officials are thinking ahead to the time when water can be piped from the Pacific Ocean and the Gulf of Mexico into the immense spaces of the Colorado River Basin and the regions of the Southwest scourged by drought.

And then we go on and quote something else quoted by the author:

> Top Government officials say success appears near at hand. The men closest to the project take a more guarded view. They say, "In 5 years we have made better than average progress."

That I suppose is your statement.

These statements are in a magazine of national coverage from an article entitled "For Water Shortage—Relief From the Sea." Now, you have not found out anything yet in your research work and activities that would lead anyone to believe that you are about ready to pipe water from the Pacific Ocean into the Colorado River Basin, have you?

Mr. JENKINS. Mr. Chairman, the matter of conveying water from one point to another is out of my jurisdiction. I do not know about that. It would seem to be more within the jurisdiction of the Bureau of Reclamation.

Mr. ASPINALL. Did you have anything to do with making these statements? Did they call upon you at all?

Mr. JENKINS. No, sir.

Mr. ASPINALL. Anybody in your office?

Mr. JENKINS. No, sir.

Mr. ASPINALL. You would state, would you, or would you not, that the article is misleading?

Dr. MILLER. Well, Mr. Chairman, I raise a question there. If the gentleman has not read the article, I am not sure whether he should offer an opinion as to whether it is misleading. You will permit people to dream a little, will you not?

Mr. ASPINALL. I am changing my question.

Do you think that the portions I have read from the article are misleading?

Mr. JENKINS. Mr. Chairman, I have not given it any thought, and I would have to give it very serious thought before I would want to say that anything is misleading.

Mr. ASPINALL. All right. Do you yourself personally, Mr. Jenkins, see anything in the foreseeable future in this program whereby waters could be economically transferred from the Pacific Ocean to the Colorado River Basin for irrigation purposes?

Mr. JENKINS. It might very well be transferred by exchange.

Mr. ASPINALL. And thereby lessen the differences that exist in the Colorado River Basin over the entitlements to the water and the use of the water?

Mr. JENKINS. Well, that is something this committee would know much better than I would.

Mr. ASPINALL. I am just trying to be a little bit practical.

Now, let me read you another statement. On February 15, the Secretary of the Interior, Mr. Seaton, made a statement before the National Farm Institute at Des Moines. The statement reads as follows:

> The Department of the Interior has a small division known as the Office of Saline Water. This office is working on a problem of the greatest importance: reducing the cost of converting salt water to fresh water. There is real hope in such research as this. Think of it: When we can economically take water from the ocean and use it for agriculture, for industry, and for human consumption, we shall have a source of water which is practically without limit. There are several methods for such conversion. In a couple of the methods, the estimated cost is now down to 60 cents for a thousand gallons. A third method can convert certain types of brackish water for about 40 cents per thousand gallons. Because of the progress that's been made, we could today supply you with converted sea water for less than the price you now pay for bottled mountain water. And we expect to keep on bringing the cost down.

I do not wish to ask you, but I would like to ask the Assistant Secretary if he cares to comment on it.

Have we reached a place where we can afford to be that optimistic, Mr. Secretary, and cause the people of the United States to feel that there is a solution in the foreseeable future for some of our water shortage questions?

Mr. AANDAHL. Just before you put the question specifically to me, I was thinking that I should volunteer a response to the question.

As you know, the Secretary was unable to go to Des Moines, and I was given his draft of address and took it out there and read it. I read it carefully before I went. As I appeared before the convention, I declared that in reading this address I could read it with the same enthusiasm, and that it said substantially the same as I might have said if I had been asked to come there in the first instance and had prepared the address myself.

The substance of the material that is in that address is taken from the 1956 annual report of the Office of Saline Water, as submitted to the President of the Senate and the Speaker of the House on January 11, 1957, and also reflects back on previous annual reports.

I call your attention to the next to the last page of the Secretary's letter to the Speaker of the House. And on the middle of that page I find a paragraph that starts with these words:

Progress during the year on several conversion processes shows continued improvement in factors affecting low-cost production.

And then it goes on to specifically state that large-scale distillation of saline water will be reduced to 50 cents or less per thousand gallons.

It is my understanding that up until the time the processes that are referred to in this paragraph were being brought into the pilot-plant stage, the lowest cost for converting sea water was around $1.75 to $2 a thousand gallons. If we now have a process, the reasonable estimate of which has gone down from that figure to 50 cents a thousand gallons, it indicates that decided progress has been made. And I do not think that it is at all too visionary to assume that we are going to go just a little further than the progress that has already been made. And I can very easily visualize that sometime within the reasonable future—and when I say that, I am thinking of 5 years or 10 years, something like that—these processes will be reduced to a cost where water will be immediately in demand for industrial and municipal uses, and perhaps on some land very near the ocean, where specialized and high priced crops are being raised, even for irrigation purposes.

I do not visualize any early transmission of water halfway across the continent, but I do visualize a time in the not too distant future when purified sea water will be used quite extensively near the borders of the ocean.

Mr. ASPINALL. Then let me call your attention to another address made by Mr. Seaton before the annual conference of the American National Academy Association in Phoenix, Ariz., when he makes this statement relative to the matter. And of course, I have to quote out of context here.

In any event, we can foresee the day when there will be networks of water pipelines crisscrossing this country in much the fashion that petroleum lines do today.

Now, your last statement is not exactly in harmony with that, because as I understand it you cannot foresee the time when we will be carrying water clear from the Pacific Ocean into the Colorado River Basin or over into New Mexico.

Mr. AANDAHL. To accomplish the vision that is expressed in the sentences that you just read, we must have lower cost energy for pumping purposes than we have at the present time, and that statement, as I understand it, is associated with the possibilities of atomic energy and the uses to which it may ultimately be put.

Mr. ASPINALL. Remember, I am friendly. I am not criticizing just to be criticizing. I am friendly to the program, and I am friendly to the officials and staff of the Department of Interior.

What I would like to get across to the public is that this is not something that is going to happen tomorrow or is not something that is

going to happen within the next 5 or 10 years, as you may feel at the present time.

Mr. AANDAHL. My statement on "5 or 10 years" was very close to the coast.

Mr. ASPINALL. I understood that, Mr. Secretary, and some of us are very hopeful and desirous that that will come to pass. But these questions have been raised by me because of the statement that Mr. Jenkins has made in his exhibit E, which shows as far as the results from the research work to date are concerned, the costs have gone up. In other words, you have learned more about the project, more about what is involved, and today you are not nearly as optimistic as you were 2 years ago and 3 years ago and 4 years ago, when the program started. Now, that is the purpose of research. I admit that. But the public should be properly advised about it and not led to believe, as they are out in my district that we are further along than we are. I represent, as you know, the upper part of the Colorado River Basin, where we have some difficulties with our friends down below relative to the delivery of waters, and we are bound by the Colorado River compact. And my people are now led to believe that the people of Colorado and perhaps Arizona are going to be able to get water from the sea, and that will alleviate our troubles and eliminate the necessity for those people down there asking for more of the Colorado River waters.

Now, you cannot foresee that picture at the present time, can you, either one of you?

Mr. AANDAHL. Mr Chairman, I think I would like to make one observation before answering your question specifically.

I do not think it is correct to say that we in the saline water program are less optimistic now than we were a year or two ago.

It is true that the cost estimate figures that we have have been refined, and we have recognized some additional problems. We have also to some degree changed and standardized our method of determining and making cost estimates. But I think that we must not conclude from that, because these refined figures are a little higher, that we are less optimistic.

Mr. ASPINALL. Just more practical.

Mr. AANDAHL. We have figures that are more realistic, but very definite progress has been made in reducing cost. And I think we have growing optimism in what can be done, instead of weakening optimism.

I do not think that anyone has intended to give the impression that in just a very short time water is going to be piped for long distances, hit and miss, all over the United States. Much of what is going to be accomplished will be accomplished by interchange, and that will result in numerous short-line transmissions.

For example, if a community near the sea coast that is now dependent upon the flow of a river for its supply of water can have that supply replaced by purified sea water with very limited transmission costs, then the river water that is going a long ways down to the seaboard town could be used in areas nearer its source. And by short pipelines going out from that river system, areas deep in the heart of the country could be reached. It does not involve the piping of the sea water clear across the continent. But that is all, a possibility of

interchange that can come with a reasonable price for purifying sea water. And I do not think that the statements that have come from the Secretary's office, which have been intended to be visionary and which have been intended to give some hope to the American people, have gone far enough so that we need to be disturbed by their implications. In fact, I think they are very constructive. I think the American people need a touch of the optimism. They need to know generally what is in prospect in the distant future. And by that information, they are going to be more cooperative and more interested in the research and experimental work that is being done by the Government to accomplish those purposes.

Mr. ASPINALL. The Chairman joins with you in your ambitions. He suggests, though, that if you were representing a segment of the population, perhaps your interpretation in public statements might be a little different.

The Chair recognizes the gentleman from California.

Mr. ENGLE. What is being done with regard to construction of pilot plants on any of these processes? Are you ready to go on a pilot plant basis?

Mr. JENKINS. Yes, Mr. Engle. We have already conducted one pilot plant test in the field of brackish waters, and we are ready to go on others within a few months. We will be ready to take the Hickman Still, which is truly a pilot plant, to the seashore for prolonged testing.

The W. L. Badger long tube vertical distillation cycle is referred to as a pilot plant, and I expect that the term is properly used, but we need to work out some very important problems, and we are taking that to the seashore. We are referring to it as a pilot plant.

In addition, we have developed a design that Dr. Lof will tell you about a little later, of a solar still, and we are taking that to San Diego in the near future, and that is also in the stage of development that I would call a pilot plant. All pilot plants—I am sure this committee knows this because it was brought up 2 years ago and the definition was made by some of our visiting scientists—involve a plant larger than the laboratory plant, on which additional problems need to be worked out. We have those four.

Mr. ENGLE. I was going to ask you about that. Just when do you get out of the field of research and get into the field of running a pilot plant? It seems to me a pilot plant ought to be a small replica of what you expect commercially.

Mr. JENKINS. It is not possible, Congressman Engle, to separate the research from the pilot plant. The pilot plant that goes to the field is for the purpose of conducting additional experiments, which are referred to as research.

Mr. ENGLE. I know that, but I am very anxious to see this program go forward with some actual demonstration plants in operation on these processes that have promise.

Now, where are you going to put these plants? Have you made up your mind?

Mr. JENKINS. Yes, sir, with two.

As I mentioned, the solar still is going to San Diego. And because facilities were available at the test station of the International Nickel Co. near Wilmington, N. C., the W. L. Badger tests are going there to begin with.

We have not selected a site for the Hickman Still. We want to operate it near Boston to see that any leaks and other problems are corrected. And we have not selected a site for that yet.

Mr. ENGLE. What is the process to be tested in North Carolina?

Mr. JENKINS. That is the W. L. Badger long tube vertical distillation cycle that he has worked out on paper for us. Mr. Badger is here as one of the visiting contractors whom we wish to call on a little later. It is a very interesting cycle, but it has not been built yet. We do not know what all of the problems are. We know of the major problem that must be solved before going further.

Mr. ENGLE. Are you working on that?

Mr. JENKINS. That is what this present contract at North Carolina is for.

Mr. ENGLE. What can you do to speed this up? Is there just so much speed you can make in research, and beyond that you are wasting your time?

Mr. JENKINS. We are doing everything possible to speed the program. The appropriations have not been quite what we needed. There is a backlog of material orders that precede ours on this long tube vertical experimental equipment. I talked long distance this morning to the people who are building this equipment in Harvey, Ill., and I asked them if they could not speed this delivery. They were to call me back this morning, if they could speed delivery. They have a heavy backlog of orders. And that is true of most of the research and development we have. Nearly everybody has a backlog ahead.

Mr. ENGLE. Which of these processes would you regard as the most favorable at the present time? The Badger process?

Mr. JENKINS. I do not think that I could venture a guess on that. We do not know what all of the actual problems will be. The estimates that have been made for us, based on greater or less information, show the W. L. Badger process to be capable, if many problems can be overcome, of producing water from sea water, without the credits for byproducts, at about $130 an acre-foot. That is an early estimate. however. With credits for byproducts; namely, electrical energy, in a multiple-purpose plant, the cost is calculated by Mr. Badger to be less. That would involve, however, the construction of steam generating plants in combination with salt water distillation plants.

Now, the freezing process, which one of the technical men, may have time to discuss for a moment, does look good. We have a contract at Carrier Corp. But there again, there is one major problem to overcome before we go ahead on a large scale. It might produce water at a lower cost than any of these distillation processes. And those remarks refer to sea water largely.

For brackish water, the Ionic type of process, the electrodialysis looks good. However, we have developed one entirely new principle that was never thought of before this program started, called the osmionic process. Dr. Gillam will discuss it for about 3 minutes later on. And if that process develops to be as good as it appears, now, it may be better for brackish water than the electrodialysis process.

Mr. ENGLE. That is all, Mr. Chairman.

Dr. MILLER. I think we may get a little overoptimistic about what we are going to do. However, I read the article that our chairman referred to in the special report on water, and I note that they say in

10 or 15 years some cities and possibly some farms will get converted sea water and before the end of the century pipelines might crisscross the country.

Well, the end of the century is quite a long time off, and I think that might be possible. As to the question of pipelines, we have pipelines running all across the country. I think Los Angeles pipes its water about 200 miles now. We have pipelines clear up from Texas to the New England States to deliver oil and gas. So pipelines would furnish no obstacle.

I do not think there is any limit to where scientific minds, free minds, can go. We should not put a ceiling on what they may accomplish. All of us in this room can remember when the poor people of today have what the rich hardly dared dream of a few years ago.

I can remember my first automobile ride in 1909. I told my father when I came home that I rode in a thing called an "automobile." Well, he said, "Son, that can't be. You can't get along without horses." And yet my father, who died a few years ago, lived to see television and all the new gadgets advance in on society.

And my guess is that it is not impossible to use brackish water or even sea water to some day take care of cities.

Take the Morse code over in the Capitol Building. Many years ago we had a ceremony celebrating the advent of the Morse code. There was the legend: "What hath God wrought." It was thought it was not possible to do these things. I do not want to put any ceiling on what we might do, and I am sure our chairman does not either, because the use of solar energy and nuclear power is coming into the picture, that has vast unknown possibilities.

I think I read in the paper just last evening where the scientific institutes down here—some of you will go to that luncheon tonight to see what some of the young scientists are doing. They are able to use a discarded naval reflector to produce half the heat of the sun, 6,000° F., to melt metals. It is a simple process. It is possible to do those things. I think the world is just opening up to what we will do with solar stills and atomic energy and things of that type.

Mr. WESTLAND. You just mentioned this dinner that is on this evening. I attended that dinner a few years ago, when some youngster came to my district. I have forgotten his name. I was very intrigued with him, because one of the first things he mentioned was launching this space satellite. We had to do it first, and the Russians would be right after us. There was not any talk about a space satellite at that time, and I wondered whether he had all his marbles or not. I guess perhaps it might have been me. Because here we are launching one of these things, I believe, this year.

So maybe if you get some of these youngsters working with you, Doctor, they certainly have unlimited horizons.

Dr. MILLER. If you read history, you will recall that statesmen of another day said that all this territory west of the Mississippi was a bunch of rattlesnakes and worthless land that could never be permitted to come into the United States as a new territory.

And as to the cost of water, I think the city of Dallas recently was paying as much as $500 for an acre-foot. So if that was to continue, I can realize that they would welcome the chance of getting

sea water at $130 per acre-foot and transporting it. That is about 56 cents per thousand gallons. So they would jump at the chance of piping water from either one of the oceans to get enough water to take care of their needs.

So let us not worry too much about it. When you are thirsty, water is worth what it costs.

I do want to urge you, and I know you cannot push science too far. My own scientific profession, medicine, has made tremendous strides. In fact, I am amazed to know that 75 percent of all the prescriptions that go over the drugstore counter now, filled by the druggist today, were not known 10 years ago or even being used or thought of. And what will happen 10 years from now—you cannot guess. You cannot put down in words what will happen. But go ahead as fast as science will let you and the funds you may have in pushing pilot plants. Because I agree with Mr. Engle. I think that you have to get this on the board. Then you have to, by trial and error, if you wish, find out which method is the better one to use. And when that is done, if you and I are here, Mr. Chairman, 20 years from now, we will wonder how it happened we did not realize we were going to take the ocean water and make potable water out of it much sooner than we thought they were going to. But push ahead as rapidly as you can within the limits of your appropriations and the limits of scientific advancement.

Mr. ASPINALL. Mr. Rhodes.

Mr. RHODES. Dr. Jenkins, we have been emphasizing the distillation of sea-water business, but you are also in the brackish water business, are you not?

Mr. JENKINS. Yes, Congressman Rhodes. And I am regretful that this hearing has somehow related largely to sea water rather than brackish water, because we devote equal attention to both. I know that in Arizona you have lots of brackish water, and this is not a program for the benefit of California and Texas only, as I believe was suggested perhaps. And even in Minnesota, which was mentioned yesterday, I find the Geological Survey has records of private wells in which the salinity ranges up to nearly twice the saltiness of the sea water. So it is a program for the entire country, we hope.

Mr. ENGLE. Will the gentleman yield?

I would like to ask Mr. Aandahl what you think of the suggestion I made that a program be set up that would permit these States that would specifically benefit, whether because of their location or because they have a great deal of saline waters, to participate on a matching basis in the development of these pilot plants. I know you would probably not want to bind the Department with reference to any views you would express now. But is it not intelligent to say that these areas that have a special interest in this program ought to be asked to get into it and to help the program go forward more rapidly?

Mr. AANDAHL. As a personal opinion, I would say that I think something like that could be worked out to advantage. We would have to be sure that the conditions for entering into a program of that kind were spelled out in such a way that we would preserve in a very substantial manner the objectives that our Office of Saline Water is working toward. But I think something of that kind could be worked out to advantage.

Mr. ENGLE. Now, of course, there are a great many places, as in the State of the gentleman from Arizona, where we have brackish water that is susceptible of much more economical purification than sea water. And if we get processes that will clean up water that is only half as brackish as the sea, we will be making very substantial progress. But that is not true, I think, of every State in the Union.

I mentioned Minnesota yesterday, and I am surprised to learn that they have some waters that are twice as brackish as the sea. I suspect that those waters would be unusable for a long time.

I thank the gentleman for yielding.

Mr. RHODES. I think the usual way of developing a process like this from the experimentation station to the commercial stage is very much the way this is developing. In other words, you get a formula or a process that you think is promising, and then you put it on a pilot plant basis. Is that not just about the way it happens?

Mr. JENKINS. Yes, sir. That is standard procedure.

Mr. RHODES. If one of these pilot plants proved to have a lot of promise, would it then be your thought to develop more or less of a commercial size plant? And then with further experimentation you could determine the exact cost of bringing this water in on a commercial basis, so to speak?

Mr. JENKINS. Yes, Congressman Rhodes. It has been our intention to carry a process forward as far as is necessary. And I understand, it was the intention of this committee and the Congress that we carry a process forward until presumably private industry would be sufficiently interested that it would carry the work the rest of the way. Where that point will come, we do not know.

Mr. RHODES. Either private industry or perhaps the department of water and power of the city of Los Angeles or some other city similarly situated on the coast?

Mr. JENKINS. Yes, sir.

Mr. RHODES. It would certainly be my hope, Mr. Chairman, that this project would continue to the point of commercial feasibility, demonstrated commercial feasibility, caused by the construction and operation of plants to produce fresh water from salt or brackish water.

Mr. ASPINALL. The gentleman from Oregon, Mr. Ullman.

Mr. ULLMAN. I just wanted to comment, Mr. Chairman, that I am certainly in full agreement with the members of the committee that the Department should go forward as rapidly as possible to develop these various methods. But I do not think that we, as a committee, should do too much day-dreaming on this subject. I know we are not. I know we are going forward. However, I want to stress that we should utilize to the very utmost all of the existing water facilities that we have. And I believe that no matter what we do on this saline program, we are going to have to utilize 100 percent of our existing water facilities, and I think probably the Department takes that attitude, too.

Mr. ASPINALL. The gentleman from Colorado, Mr. Chenoweth.

Mr. CHENOWETH. Mr. Jenkins. I am very much interested in your statement and the presentation of what you have been doing and the reports on the different processes.

I am not quite clear in my own mind as to how many different processes are now under consideration. I understand you have eliminated

some. Some you have found not practicable, and others do not appear to be feasible.

How many are under active consideration and experimentation at this time?

Mr. ASPINALL. Will my colleague yield?

Just as soon as we finish with these gentlemen, we are going to have the specialists in these fields, who will discuss the specific processes being studied.

Mr. CHENOWETH. Good.

I am just curious as to how many there are.

Mr. JENKINS. There are six general major fields that we are working in, and even those six could be combined into five, because we have separated the distillation into two. Those consist of distillation, freezing, solar distillation, membrane processes. Those are the principal ones.

Mr. CHENOWETH. You have about five processes, then?

Mr. JENKINS. General processes; different adaptations of those principles.

Mr. CHENOWETH. Are they all competing with each other now to see which one will cross the wire first?

Mr. JENKINS. Yes, there is some good healthy competition. We have, of course, always been confronted with what I might call the enthusiasm of each proposer. Each man naturally thinks his process is the best, or he would not have proposed it. If he thinks that someone else has a process better than his, he probably would not——

Mr. CHENOWETH. Then there are five now competing with each other.

I believe you were asked if you had come to any conclusion as to which process may be the most promising.

Mr. JENKINS. It is a dangerous thing to make such a guess, because we are encouraging everybody to work on the problem until we get all of the answers. And we have had this experience: that when some persons feel there is another process that is better than theirs, they become discouraged and may quit work. And we do not want them to do that.

Mr. CHENOWETH. There are about five, then, that you want to keep going in this experimental work. Each one feels he has something to offer, and you feel they are all enthusiastic about their processes, and you want them to continue.

Mr. JENKINS. Oh, yes, sir. They are enthusiastic. Their enthusiasm is tempered with their professional scientific training.

Mr. ASPINALL. The gentleman from California, Mr. Utt.

Mr. UTT. I first want to congratulate the Secretary, and also Mr. Jenkins, on a very complete report.

This is the first comprehensive report that has brought us up to date, and I think I have gotten more out of it than in any of the other hearings we have had. And I want to say to you that southern California is not about ready to relinquish its rights to the Colorado River water to the States of origin based on the hearing we have had here this morning.

Mr. ASPINALL. May I reply to my colleague that I knew the gentleman's position would be that. I just wanted to find out what the gentlemen of the Department had in mind.

Mr. UTT. The city of San Diego and also the city of Los Angeles, I know, would participate in these pilot plants, because they have been considering from time to time initiating studies of their own. They would have to start at the beginning, and their money would be much better used, I think, in the participating projects where it would be under your control and direction, and I think that might well be explored. I had a schoolboy from out in Fallbrook write me a letter the other day with the suggestion that if there were a prize offered of $100,000 for a method that could be worked out cheaply at, say, $25 or $30 an acre-foot, some of these young brains, like the boy on the $64,000 question, might come up with something that would surprise some of the older heads.

Mr. RHODES. Would the gentleman yield? Was that by Richard Yackey?

Mr. UTT. That boy was Richard Yackey.

Mr. RHODES. Richard Yackey used to live next door to me in Chandler, Ariz., when his dad was at Williams Field, and I got the same letter, but it was a million dollars when I got the letter, and I wondered where he dropped that $900,000. I certainly commend this young man for his fine idea.

Mr. UTT. I might say that the cost of water varies so terrifically on a comparable basis.

In the Imperial Valley it is $2 or $3 an acre-foot, and in the San Marcus Valley they are paying up to $100 for the farming, because with their tax and capital outlay it runs up as high as $70 a year per acre, and then there would be an additional amount for the operating cost for the water itself. So we cannot be considering that this is not successful until it reaches the $3 or $4 stage.

We want to congratulate you again for the comprehensive study. And more facts have been presented. I admit that I am set back a little. I have made some speeches in my district which I will have to revise.

I am glad to have this information, and I want to thank you for bringing it to us and also for submitting this article to the Scientific American. I have heard about it, that you have prepared it and submitted it, and that you have refused the price that have they offered you for writing it, and I want to congratulate you for that and for the public service you have rendered.

Mr. BURNS. I have no questions, Mr. Chairman. I just want the record to show that Hawaii has great interest in this.

Mr. ASPINALL. The Chairman is well aware of your problems over there. He congratulates the people of Hawaii that they have done what they have to solve their water supply problems.

Mr. MCFARLAND. Mr. Jenkins, the four processes you mentioned, that either have gone into pilot plant stage or are ready, are the Hickman still, the Badger cycle, the solar still, and the Ionics membrane process. As I understand it, of those four, only the Badger cycle pilot plant would produce any substantial amount of water. What would be the water production from that pilot plant if your scaling problems are solved and you go to pilot plant stage?

Mr. JENKINS. That production could range—I would like to have Mr. Badger answer that question in a little more detail but we have some designs prepared by him which are on the basis of 17 million

gallons a day, and then there are some engineering estimates of a smaller plant that were made at our request, of about a million gallons a day.

Mr. McFARLAND. In other words, you do not know yet what size plant you would go to? I am trying to determine what the cost of such a plant might be, and whether or not that is within your present authorization.

Mr. JENKINS. Yes, sir. The plant that we have given most attention to is one which would produce the 17 million gallons a day if it were successful. It would cost, according to Mr. Badger's estimates, in the neighborhood of $7.6 million.

However, a smaller plant could be built as a pilot plant, and you might wish to ask him about the costs on it.

We have always expected that if the scaling problems were overcome in this test in North Carolina, it would probably be necessary to ask for further authorization. And I mentioned that in my testimony yesterday, but not specifically.

Mr. McFARLAND. What is the estimate of time required in this research on the scaling problem?

Mr. JENKINS. We estimate a year of experimentation after the equipment is erected. And it will be at least next November before the equipment is erected, I believe. We are trying to hasten that.

Mr. McFARLAND. The other matter I would like the committee to have your views on is this: You mentioned the need for a central research and testing center near the sea. Now, would you advise the committee on that?

Mr. JENKINS. We have felt, and we have reported in two annual reports, that we need a research and testing facility. Here we are borrowing the facilities of the International Nickel Co., and we are borrowing a piece of land from the city of San Diego, and we do not know what we are going to take from the Hickman still. And we know that we will have to place 1 man at each of the 3 places.

It has seemed to us that we would have better exchange of information, possibly at lower cost, if we had a small central laboratory on the seashore ourselves. It need not be a big expensive thing. One of the men in my office has calculated that our needs could be served with an expenditure of $500,000, and on very careful detailing we have cut that down to $300,00, but I think we would want for many things at $300,000.

Mr. McFARLAND. Do you consider that you have authorization to do that?

Mr. JENKINS. Yes.

Mr. ASPINALL. Thank you very much, Mr. Secretary and Mr. Director.

If you gentlemen will take your seats back in the audience, we will call up the experts. And when we get through with their testimony, if you wish to join them to help out in answering the committee's questions you may do that.

Mr. JENKINS. May I inquire as to the order?

Mr. ASPINALL. Unless there is objection, we shall listen to the statements of the next three witnesses, Mr. Cywin, Mr. Lof, and Mr. Badger.

Do you have any copies of your statement, Mr. Cywin?

STATEMENT OF ALLEN CYWIN, OFFICE OF SALINE WATER, DEPARTMENT OF THE INTERIOR

Mr. CYWIN. No, Mr. Chairman; I do not.

Mr. ASPINALL. You may proceed.

Mr. CYWIN. Thank you, Mr. Chairman and members of the committee, for affording me the opportunity of speaking before you today.

Less than 3 years ago the Department entered into a contract with the Badger Manufacturing Co., with Dr. K. C. D. Hickman, as consultant, for the development of the rotary vapor compression distillation technique. This important advance in distillation techniques provided for a means of greatly increasing the rate of heat transfer to the feed water by spreading the saline water out in a thin film under centrifugal forces. Thus, a more efficient use was made of the heat of compression as compared with more conventional distillation equipments, particularly at low temperatures necessary to minimize deposits from the sea water.

At the beginning of this research and development program by the Badger Manufacturing Co., it was necessary to build a small still of this type, of durable materials in order to verify the high rates of heat transfer by this method, and also to illustrate the practical possibilities which existed for its use on distillation of sea water.

Slide, please.

This first unit built under the contract has a rotor, which formed the evaporation surface of only 18 inches in diameter. The unit would produce about 100 to 200 gallons per day of fresh water from sea water. However, there were a number of variables which needed to be verified in order to obtain ideas on the best designs for a larger unit.

Some of these tests were carried out on the small No. 3 unit. The answers to other problems which could not be obtained on a unit that small made necessary the construction of a larger experimental model, which had a rotor in diameter of 4½ feet.

Slide, please.

This is the No. 4 unit with the top half of the cover removed. You can get a good idea of the rotor inside.

Slide, please.

This is a schematic of the No. 4 unit. The sea or saline water feed is sprayed on the inside of the rotors, part vaporized, is withdrawn through the compressor marked B, it compresses then condenses on the outer side of the rotor, and evaporates a like amount of sea water feed. The distillate is then withdrawn.

By use of these two pieces of equipment in the laboratory, the Badger Co. developed the designs for a much larger unit having a series of 8-foot-diameter rotors.

A second contract was then entered into for further research and for development and construction of the larger still.

This larger unit was designed to be able to produce about 25,000 gallons per day of fresh water from sea water if operated at a temperature of 125 degrees Fahrenheit. Operating at higher temperatures can increase capacity if formation of deposits or scale can be prevented. Recent experiments with the No. 4 unit have shown that an operating temperature of 150 degrees Fahrenheit is feasible without serious trouble from scale formation.

The No. 5 unit was designed of such size that engineering data could be obtained by its use which would be reliable in predicting the operation and cost of such equipment if it were to be produced on a larger scale.

We will now see a series of slides on the assembly of the No. 5 unit.

First, this is a schematic, a cutaway, of what the No. 5 unit will look like. The flow diagram is exactly the same as in the smaller units.

Slide, please.

These are the eight rotors. They are approximately 16 feet high, 8 feet wide.

Slide, please.

On the right-hand side, we see the shell that will contain the eight rotors. In the foreground we see the top of the dome, with the motor to operate the compressor.

Slide, please.

Here we see the rotor assembly being lowered into the shell.

Slide, please.

These are the heat exchangers and some of the auxiliary equipment for the No. 5 unit.

This unit is now being made ready for testing at the Badger Co. in Cambridge. It should be emphasized that this type of vapor compression distillation equipment is entirely new and that there was little in the way of previous experience to call upon in its development. The No. 5 unit, although considerably advanced over the first small single rotor models, is still an experimental piece of equipment. It has been constructed for the purpose of obtaining test data—particularly test data under actual operation conditions on sea water over extended periods of time. In this way, the problems and difficulties which are always encountered in the development of any new process or piece of equipment can be determined, analyzed, and overcome. Such extended operation and study will also make possible a better evaluation of the possibilities that this type of equipment offers in lowering the cost of producing fresh water from salt water.

Thank you.

Mr. ASPINALL. Thank you very much, Mr. Cywin.

We will now have the next witness, Mr. Lof, come to the witness stand to present his statement on the solar distillation process procedure.

STATEMENT OF GEORGE LOF, CONSULTING ENGINEER, DENVER, COLO.

Mr. LOF. Mr. Chairman and gentlemen, I believe Mr. Jenkins told you that I am a contractor for the Office of Saline Water and particularly concerned with the solar distillation processes, of which you have been briefly informed. I do not have a written statement, but I would like to present a brief discussion of the principles involved in the solar distillation and a summary of where the program now stands in this field and what the prospects are, and where we are headed.

I am a consulting engineer, chemical engineer, with my office in Denver. My principal concern has been with applications of solar energy for approximately the past 12 years, and I have had a parallel field of activity in water resources, and it is, I think, very natural that

I am vitally interested in the possibilities of the solar distillation system.

I believe that I am keeping the solar distillation method in perspective along with the other processes, because of advisory activities I also engage in with the Office of Saline Water and other organizations. So I hope that I do not appear prejudiced in favor of the solar distillation method. As a matter of fact, I believe that there are going to be places in the world and in the United States where solar distillation will be the answer, and other places where obviously other methods will be superior.

The method is basically attractive, because it is a trick of nature that most of the areas of the world where fresh water is scarce are blessed with plentiful sunshine. So to put these two situations together is, of course, reasonably logical at the outset.

Of several methods for applying solar energy to sea water evaporation, the simplest and perhaps the most economical is an almost crude type of apparatus, just about the simplest one could visualize.

If we imagine this table as having a shallow rim around it, perhaps 2 inches deep, and the table then filled with salt water, and then have sloping glass sheets covering the table and a foot or two above it, and then expose this to the sun, we have a simple solar distiller.

The sun heats the water in the basin. Usually we blacken the bottom of the basin to increase absorption. The water slowly evaporates from the basin and condenses on the cooler glass covers. Then the water runs down the sloping glass covers into little troughs at the lower edges and then runs out to storage.

The unevaporated salt water then leaves at the other end of this distilling unit and is discarded.

This system works very easily. We really do not have to do much research on finding out whether it will work or not.

The whole question is: Can we produce water from it cheaply enough?

One at first sight might say, "Well, the energy is free." The energy costs nothing, so all the costs involved are the fixed cost of the installation—the investment cost, plus maintenance expenses. And these are the costs which we have to minimize—construction cost and maintenance expenses. It is an old process which was used back in the 1800's in Chile to supply fresh water at a copper mine way in the Andes, and there has been very little improvement in the process until the Office of Saline Water began working on it just a few years ago.

Mr. ASPINALL. May I say to you that Dr. Telkes brought us up to 2 years ago on this particular matter. She went into more or less detail in explaining the fundamentals and the history of it.

Mr. LOF. Thank you. Then I will show briefly 3 slides, now, and then 6 more in a few minutes.

This is a solar distiller built in the Virgin Islands a few years ago under another Government program, the performance of which was analyzed under the Office of Saline Water program. I think you can see from my description the way the unit is built—very small size.

The next slide, please? This is a program at the University of California, which was underway at the time the Office of Saline Water was initiated, showing somewhat larger size units, but still on a very small operating level at that test station.

The next slide, please? And these are some solar distillers in north Africa, in Algeria or Morocco, of very small size, however, representing the first real practical application of solar distillation. These units are being made in considerable numbers for supply to the arid towns far inland, where the only source of water is very brackish underground water, which can be distilled for drinking water for families.

Thank you.

There have been several steps taken forward now under the Office of Saline Water since the establishment of the program. I think these can best be summarized by a brief description of the present program and plants.

There actually have been 2 very substantial breakthroughs in the project just during the past 18 months.

The first of these has been in design, and the second in materials.

Up to this time, we had been thinking in terms of these distilling units up on legs, fabricated of wood and other materials, subject to considerable maintenance problems, but very recently we have worked up a design of a large concrete distilling basin, built with the economies possible with large-scale concrete construction. This basin is subdivided by shallow walls, above which glass covers are mounted to collect the distillate. This is the unit which will be built in San Diego this year. It will have an area of about 5,000 square feet and will produce about 500 gallons of water per day.

The new design involves the concept of a deep layer of water rather than a shallow layer, whereby the unit will operate at night as well as in the day, because of heat stored in the water during the daytime and which, because of its design, should have exceptional economies in construction and very simple maintenance problems.

The other development, which is very significant, is in the field of plastics. At least two new plastic films have been announced in the past few months. And with the du Pont Company cooperating in the project, somewhat smaller distilling units employing these plastics will be built at the San Diego installation also.

The newness in the films is in the weather resistance which the company feels has been incorporated. Up until a year or two ago, we knew of no film which had a service life which could be expected to be longer than about a year. Well, replacement of a large plastic installation every year would be unthinkable from the standpoint of cost, but these new films may have lives exceeding 10 years, and thus we are now approaching something which looks very practical in the field of plastics. I would like to point out, here, that even as recently as 18 months ago, it would not have been possible to go ahead with pilot plants in either of these areas, because we just did not have the basic information available.

There are other projects in the solar distillation field of more pioneering nature. I believe you have heard of Dr. Telkes' work, as the Chairman has said. And that is proceeding, with the study of new designs of distillers, an inclined distiller, which has a somewhat higher yield of distilled water per square foot of area exposed, and a multiple effect distiller, which utilizes in effect the heat of the sun several times in producing water. These will have higher productivity per unit of area or per unit of sunshine, but I want to point out that this is not the criterion of success in the program, because the energy

is free. So it does not matter what efficiency we have per se. What is important is how much water we can produce for a dollar of investment with maintenance costs being within reasonable limits.

Another pioneering program is at the University of New Mexico, where storage of solar heat is being verified, and the properties of some of these new plastics are being evaluated at the Bjorkston Research Laboratories in Wisconsin.

Just a word about costs. As the Chairman has pointed out very effectively, there is a tremendous range and considerable disagreement in the field of costs of distilled and of demineralized water. This is particularly true in the case of solar distilled water. Most of these other processes have as one of their major costs, in the cost of the energy to operate the process. And in general, the costs of the energy is pretty well established, or can be reasonably closely approximated, in most of these other processes.

Well, with solar distillation, the energy cost is nothing. The entire cost is wrapped up in construction and maintenance. Well, no sizable solar still has ever been built in this country; so we do not know what construction costs are, and we have little idea of what the maintenance expense is going to be.

So most of our cost projections in solar distillation are very approximate, and you can get a wide range, depending upon the assumptions that have been made by the proponents and the engineers making the estimates.

I volunteer now my own opinions as to the costs of these new developments, these two new developments, approaching the pilot plant stage.

The type of still being built in San Diego, the concrete distiller, in a many acre size installation, should be able to be built for considerably less than a dollar per square foot; and if maintenance expenses are not excessive, it should make water producible at less than a dollar per thousand gallons.

I may have this thrown back at me some years hence as being too high or too low, but I think that I can justify a position that it will be less than a dollar per thousand gallons. That is approximately $330 per acre foot as a maximum.

The plastic stills appear to have equally good and perhaps better prospects, but the maintenance problem is somewhat more uncertain.

I have seen some estimates of the duPont Company showing the water cost to be in the vicinity of 50 cents per thousand gallons or perhaps even less.

And then a few slides to close my discussion, showing the present program.

These are the inclined solar distillers being verified by Dr. Telkes at New York University. The principle is basically the same, but a slight difference in design is involved. These are still being studied on a small scale.

The next slide, please? These are some plastic distillers which were verified at the Bjorkston Research Laboratories.

At that time there was no plastic known to be sufficiently weather resistant to be practical. Nevertheless, the program was conducted in the hopes that there would be practical plastic developed which would serve the purpose. These units were therefore used in determining the performance of these distilling units.

And here is another design of a plastic distiller tested at that installation.

This is an artist's conception of the concrete and glass solar distiller to be built at San Diego this year. I believe this view is roughly half an acre, and it will be approximately one-fourth the size of the picture. There will be 6 of these tent shaped enclosures, 100 feet long by 8 feet in width, each one.

Dr. MILLER. How much will that produce today?

Mr. LOF. About 500 gallons.

Dr. MILLER. A day?

Mr. LOF. Yes.

Dr. MILLER. You could not operate it for a few cents a day, then?

Mr. LOF. Oh, no. This unit will certainly not operate at costs anything aproaching that. I believe that I said in a multi-acre installation, even approaching a square mile, the costs would be reducible to something in this order of magnitude.

The unit is designed, however, to give us maintenance data and operating data, which should be readily translatable to much larger scale operation, and we hope that construction costs will be likewise convertible.

The next slide? This is the duPont plastic distiller. Not only is a new film involved, but some novel designs have been worked out, and instead of supporting the plastic film on an expensive framework we simply use a very slight air pressure inside the envelope of plastic maintained by a very small blower. The water distills in the same basic principle.

This slide shows another view of the plastic film type of distiller, air inflated. These will be built in approximately the same cross section, but 100 feet long and in multiple units.

Thank you, Mr. Chairman.

Mr. ASPINALL. Thank you very much. Will you remain at the table?

Mr. Badger, developer of the Badger multiple-effect evaporation process, will take a chair at the witness table.

How long will it take you, Mr. Badger, to make your presentation?

STATEMENT OF W. L. BADGER, CONSULTING ENGINEER, ANN ARBOR, MICH.

Mr. BADGER. Mr. Chairman, I can compress what I have to say into almost any time you set.

Mr. ASPINALL. We do not want you to compress it too much.

Will it be all right for Mr. Badger to have 15 minutes? We can stay here until 12:30.

Mr. BADGER. I would prefer to do less talking myself and spend more time answering questions.

Mr. ASPINALL. You take just as much time within the 15 minute period as you need, and we will proceed with the examination.

Mr. BADGER. I should explain first that I have no connection with the Badger Manufacturing Co. They are two entirely different branches of the family. You have to run back before 1700 for the 2 to run together.

I should explain the reason why I am mixed up in the evaporator projects and that is this: I taught chemical engineering at the Uni-

versity of Michigan for 25 years, and in the spring of 1917 the Swenson Evaporator Co., who are the largest producers of commercial evaporators in the United States, asked me to leave the university and build a research laboratory for them.

When I found what fundamental research they wanted to do, I advised them to build a laboratory at the university, which they did. And that laboratory, which involved—when I say "laboratory," you think of beakers and test tubes and flasks and things of that sort. It did not. It involved full size evaporators, some standing 35 feet high, and capable of evaporating four or five hundred pounds of water an hour. That was built at the university. I was in charge of that laboratory, both as the representative of the university and of the Swenson Evaporator Co., for 30 years, from 1917 until 1947.

During that time, I have published more original research papers on the theory of evaporator design than anybody else in the world. Consequently, I feel I have some right to talk about evaporators.

I entered this project with 1 basic principle in mind—with 2 basic principles in mind, rather.

The first was that there was a type of evaporator that was extremely cheap to build that the other people in this field had never thought about.

The second idea was that I did not think any of the people who had been playing with sea water distillation had ever begun to appreciate the possibilities of complicated flow sheets such as we know in the chemical industries. Therefore what I have contributed to this thing is, first, the suggestion that there is a type of evaporator built that is much cheaper than anything else that has ever been talked about yet, and, second, that I have had a lifetime of experience in laying out evaporators and evaporator combinations which I think has helped some.

Now, I have a few lantern slides, and I am going to push them just as fast as I can.

I am throwing this slide on to give you an idea of the type of evaporator I have in mind. It is simply a cylindrical shell with a great many tubes in it. The liquid is introduced here, goes up through the tubes, and boils as it rises. Steam is introduced here, and the steam surrounds the tubes. And the vapor goes off through an entrainment separator. That is cheaper per square foot than any other machine we can possibly put in and it is a type of evaporator which has had tremendous use both in this country and abroad.

The next? This is a very lowbrow schematic idea of what we are trying to do. It is necessary to have a certain difference in temperature between the steam that heats the evaporator and the water that is boiling.

Let us suppose that is a steam boiler. That exhaust goes through a heating pipe in this evaporator and boils the water. Some of that vapor comes over here, and this second effect is at a lower temperature, so that this steam is hotter than this boiling water, and we boil for added effects, which is called a multiple effect evaporator, a principle which has been known for better than a hundred years.

Now, let us suppose that this evaporator is operating at a specific pressure. This is at 212° F. and this water is boiling at 212°. If we take some of that steam and compress it in an ordinary compressor, we can compress to where it is hotter than it was before. That is

what we call thermocompression. And this illustrates, then, a cycle in which some of the steam is compressed, but the exhaust from the compressor goes down through mutiple effects.

Now, that is essentially the scheme that I am proposing for the large diagrams.

Now let us see the next one.

This is a layout of exactly what you saw in the previous slide, except elaborated into a large scale economic plant. There is a boiler and a power generator, two turbines. The exhaust from those turbines goes over here. The red is steam, and the steam operates this multiple effect evaporator. Part of the steam is taken off from these evaporators and pushes back through those. I do not expect you to know anything about this, it is so complicated and involves so many details I am not going to attempt to go into those at all. I am just going to point out that it can be a devilish complicated thing before you get through, but not too complicated to be practical.

We do not have to do it that way. And this is a trick that should have been thought of a long time ago and was not. Let us say we have a steam boiler and a steam turbine.

Now, in an ordinary standard powerplant, which is this, the turbine exhausts clear down to here. Suppose instead of working this turbine with 26 inches mercury, I went to 10 or 15 pounds gage. I do not get quite as much power out of a pound of steam going through that turbine as if I had a vacuum, but I can take that exhaust steam and run a multiple effect evaporator, and I do not get as much power as I got before, and I do not get as economical an evaporator out as I did before, but the combination of the two beats the other scheme all hollow. And I do not want to get you gentlemen excited. This plant, the plant I showed you before, sold only distilled water. This plant sells juice and water. And the question of what the water costs is a question of what you can get for the juice.

Now, we have prepared flow sheets that indicate that if we can sell that juice for 4 mills a kilowatt on the bus bar of the powerplant we can make distilled water for somewhere around $100 an acre-foot, maybe less.

On the other hand, if you could sell this juice for 6 mills at the bus bar, you would get your water for free.

Now, that is perfectly good economics. There is no joker. There is no funny business in that anywhere. But before I go ahead with any of these schemes, there are certain problems involved in the application of this long tube evaporator to a saline problem.

In order to give you some idea of the fact that these are practical installations, there is an installation of 7 of these long tube evaporators in a pulp mill down on the gulf coast which is evaporating waste pulp liquor, and for even a 17 million gallon per day plant we would only have to have evaporators about a third larger in diameter, but the same height as those.

In other words, it is a step that is perfectly reasonable to make from an engineering point of view.

Now, I have two problems involved in the application of this long tube evaporator for the distillation of sea water. Up to the present time, the long tube evaporator has never been used on scaling solutions, solutions that form scale. Therefore, I have got to see if I can keep scale out of these machines.

I have two possibilities, both of which I want to investigate. I am fully confident that we will find a way to do it.

I have spent a great deal of time and many years in the evaporation of salt brines, to make ordinary garden variety table salt. Calcium sulfate is the stinker that causes most of the scale in evaporators. It used to be that we expected to shut down an evaporator every week, put in some men and drill the tubes out and drill the scale out. Today I know of one big evaporator set that has been on the line for 5 years and has never had a tool in it, and the tubes are as clean as the day that we started off. Now, we did not accomplish that overnight, but we do know how to handle calcium sulfate scale. And I am just betting that the principles we used in licking the calcium sulfate scale problem may have some effect on the calcium and magnesium carbonate scale using these evaporators to distill sea water. Therefore I am proposing to build a pilot plant for which the appropriation has been made in the equipment ordered. And this is the test evaporator. It looks like a toy, but it is not. We are using tubes 26 feet long in that evaporator, because in testing scale you have got to run a tube of the proportions that you expect to use under the conditions that you expect to use in order to tell whether scale will form or not.

Now, if this is the test unit on which we will make our runs, I have put 5 or 6 different metals in there so that we can see what happens. But if I expect this to run seventh out of a set of 12 evaporators, it must be fed with not fresh sea water but the feed it would get in going from the sixth to the seventh effect in a multiple effect evaporator. Therefore, I have another evaporator over here and this will be controlled so that it will discharge exactly what we need to feed to this evaporator, and thereby insure that the test conditions represent just how that evaporator would be running.

This evaporator is a thing I am putting in that has to do with some of our stunts on scale prevention. But I want you to see that this is not a toy.

And we talk about research, but it is not a matter of test tubes and beakers and glassware on a laboratory bench. It is pretty good sized equipment. Those that you see there will stand over 30 feet high. But they are susceptible, they are so instrumented that we can get exceedingly accurate quantitative results out of that test set up.

Now, it is going to take time. All this equipment has been ordered, but the evaporators won't be delivered until the end of next summer. And if any of you gentlemen know any magic words that can be said over the contractor to speed up that delivery, that will help us. It is going to take time to do the experimental work, because, for instance, I have had a great deal of experience in running scaling tests, and I do not trust an experiment of this sort to tell me whether a tube is going to scale or not unless I run it at least a week, 24 hours a day; absolutely continuous operations for a week, 24 hours a day. Then, if we have accurate enough data, I can tell whether the rate is beginning to fall off or not.

This is to hold an evaporator without scale for a week.

In the plant, I want it to run years without scaling. But I can usually guess from a week's run pretty closely.

But there are a lot of different sets of conditions that can be duplicated in this evaporator, and all of them have to be checked to see whether we can make the thing go.

As to how long that will take, it is anybody's guess. If the Lord is with us and these things come out with good answers quick, I might be through in six months. I think a far better bet is about a year for the experimental work. And the question is: How long before we can build one? Well now, that depends on how badly you want it.

During the war I was in charge of a plant that was built out at Las Vegas to recover low-grade manganese from low-grade manganese ores. It was a serious emergency. When we started to build that plant, there was only a 3 months' supply of manganese in the United States, and the Germans had U-boats in the Caribbean, and they were sinking our cargoes of manganese ore from Brazil. We had to build the plant. We did not have the data. We just had to make the best guess we could and hope it would work.

Now, it did work. We made manganese, and we made manganese in time to prevent an emergency. But the plant never got up to 50 percent of its capacity, and the manganese cost about 5 times as much as it ought to because 357,942 different problems arose in that plant, because we had not been able to back it up with the necessary research ahead of time.

Now, if there were an emergency like that, I would build you this plant tomorrow. I would start the engineering up tomorrow. But there would be a lot of jokers in that design, and I would just simply have to hope that it worked out all right. And if those jokers proved to be bigger than I thought they were, and the plant made a lot of trouble and did not work very well, and the costs were high, and so on, you would say, "Well, what kind of nincompoops are fellows Jenkins and Badger to talk us into putting money into a plant of this kind that does not run?"

So under the circumstances, I think we had better do this first, and then when we have a design we will know that it is going to work.

Now, the engineering of a 17 million gallon plant is going to take pretty nearly a year, and probably if our experiments seem to give us promising results at the start, it might pay to begin the engineering before this pilot plant job was over. But the question of how soon you can get one of these plants is the question of how big a gamble you want to take.

If you want to take a big gamble, I'll build you one now.

If you want to play it safe—and this is what I advise—you will wait until we get these answers before you yell for a big plant. But it can be done.

Now, I have two things to offer in this scheme. First, I am using only known equipment. All the stuff that I am going to put in these flowsheets is stuff that you can go out and buy on the market that is well understood today. I have not got to develop anything except to prove to myself that these tubes won't scale. But the type of evaporator, the type of accessories, the compressors, and everything else, are standard commercial units that I got firm quotations on from the manufacturers of that equipment. That is, I am not trying anything experimental, except that I am running a much more complicated flowsheet than most people would tackle.

The second thing that I have to offer is better than 40 years of experience in designing evaporators, some of them for very complicated situations, and I believe that out of that experience I can furnish a cheaper flowsheet than has been suggested so far.

Now, I am not going to argue with Mr. Jenkins about costs, because you cannot say that any cost estimates are absolute. You take one problem. How fast do you want to amortize your capital? What do you want to allow for taxes and insurance?

There are a lot of arbitrary figures that have to go into one of those estimates. And I used one set, and Mr. Jenkins has recently gone over it with another set, and I cannot say that mine are any better than his or any worse than his. But these flowsheets will give distilled water, I would say, about 30 cents a thousand gallons. Mr. Jenkins says about 40. And I do not feel that there is very much uncertainty there.

If you can find a power company that is willing to try the second flowsheet I laid out, where we are using the exhaust from a power unit to produce distilled water, and if they can sell power for more than 4 mills on the bus bar, you can get water at a lot cheaper than 30 cents a thousand gallons. And right now. I do not mean after years of experimental work.

I have got to check that scale problem, and that is all.

The rest is all well-known equipment.

Mr. ENGLE. Do you feel reasonably confident, Mr. Badger, that you can control that scale?

Mr. BADGER. I am very confident of that, because I have two ways of doing it.

One was the stunt I used in salt evaporators, which was very successful.

Mr. ENGLE. I could not hear your last statement.

Mr. BADGER. The one thatI have used in the past in preventing scale in salt evaporators. And every big salt evaporator in the United States is now using that system. That is for sulfate scale, and I do not know how many problems will be involved in transferring it to a carbonate scale, but it has a pretty good chance. If it does not work I can always acidify the sea water, and it is well known that if you keep the sea water slightly acid you do not get any scale. But that usually means a little more expensive metals in the construction, not expensive enough to raise the cost of water by more than a few cents a thousand gallons, but I just simply would rather not get into those metals.

And the equipment that I have shown you and the statements that I have made up to the present time involve building this equipment of ordinary common or garden variety plain steel, low carbon steel.

Mr. ASPINALL. I suggest that you take your seat at the witness table now, Mr. Badger. I understand your statement is finished. And perhaps we can divide the time so that each member of the committee will have adequate opportunity for questioning.

Mr. ENGLE. You say that you think you can hit in the neighborhood of 30 cents a thousand gallons?

Mr. BADGER. Somewhere between 30 and 40 cents, depending on the way you made your estimates.

Mr. ENGLE. That would be from $100 to $130 an acre-foot.

Mr. BADGER. Yes.

Mr. ENGLE. And that is right now?

Mr. BADGER. Yes, provided I can lick that scale problem. That is the one big "if."

Mr. ENGLE. And you feel confident that you can do it?

Mr. BADGER. I do.

Mr. ENGLE. How long will it take?

Mr. BADGER. My best guess is about a year's experimental work. As I say, if the Lord is with me and the experimental work gives unusually favorable results, it may not take anywhere near a year.

Mr. ENGLE. And what are the prospects of reducing the price below 30 cents a thousand gallons?

Mr. BADGER. Always when you get as complicated a flowsheet as this and try to put it into practical operation, problems come up. And it sometimes takes quite a little time to work them out. But invariably, the working out of those problems—there are little bugs that appear in practice—results in a continually decreasing cost. I cannot predict how much.

The two most important factors in the cost of water by this flowsheet are, 1, the cost of the equipment; and, 2, the cost of the energy, that is, the heat, the steam.

Mr. Jenkins has asked us to figure on the basis of a certain price per million B. t. u.'s in fuel. If this first plant should be built out on the west coast, I am certain that the fuel might be 15 or 20 percent less expensive than we have used in these estimates.

There are always extras in the first plant of this sort that have to be put in the estimate for contingencies. The first one may very well cost a little more than we think, but the 3d or 4th or 9th or 17th is going to cost a great deal less, because the equipment and its operation will be standardized.

In other words, to specifically answer your question, I think that there is an excellent possibility that in the first few years after this thing is started, the costs will gradually drift downward.

Mr. ENGLE. What is the single most constructive thing that Congress can do in making this program go forward more rapidly?

Mr. BADGER. Not very much.

Mr. ENGLE. I am asking this question to all three of you.

Mr. BADGER. Not very much. As I say, if you know some magic words you can say to the manufacturers of this equipment that will get me delivery a few months faster—

Mr. ENGLE. Yes, "bonus in cash." Those are the magic words.

Mr. BADGER. If you gentlemen will all out and pray for success on our experimental work, that may speed it up. But it is nothing that I can predict. There is a lag here, until I can lick this scale problem, that nothing but just plain elbow grease will lick.

Mr. ENGLE. I would like to have the other gentleman answer the same question.

The question is: What is the single most constructive thing Congress can do to move this program forward with more rapidity?

The gentleman in the center.

Mr. LOF. Mr. Engle, if I could answer your question in this way, there are two types of projects now being supported, one on the developmental engineering pilot plant side, efforts to reduce costs, and the other in the more basic research side, which largely is trying to develop ideas and new break-throughs in technology.

Frankly, I do not know of any magic formula to generate ideas. I do not think more funds are going to generate any more ideas.

They are something which I think largely are independent of the finances involved.

Mr. ENGLE. But they are not independent of the brains that produce them, and it takes money to make those brains available and to free those brains from being troubled with other matters which require the earning of money. So I do not see how you can separate them.

Mr. RHODES. I take it, then, Mr. Lof, you feel we still do not have the process we really need to produce this water on an economical basis?

Mr. LOF. We do not have it that we can now immediately build and compete with existing municipal supplies.

However, we have several processes which I believe, when developed, will produce water competitively with new supplies of water which are soon going to have to be called upon.

But to comment on Mr. Engle's point, if we were to hire men full time to work on this problem, then funds probably would engender new ideas. However, the way most of the ideas have been developed is by persons, individuals, organizations recognizing that this need existed, recognizing the program's existence, and submitting ideas to the program for evaluation and support. And in my own opinion, the ideas that have come in, that have shown promise of success and that have shown merit, have been supported.

Mr. ENGLE. May I get the answer of your associates to the same question? I would like to know just what we can do.

Mr. CYWIN. Congressman Engle, I think that you are doing something here today. You are focusing attention on this problem. By so doing you are encouraging our contractors and potential contractors—encouraging their interest in this field.

Mr. ENGLE. I want to do something tomorrow. And I cannot spend all my time cackling. I have to get an egg laid.

Mr. CYWIN. Let us go back to the W. L. Badger cycle method. This idea of producing electricity and water is not new. We use this aboard naval vessels today. The uniqueness in this idea is the different type of evaporator, which has never run on sea water for water production, and its method of scale prevention, which we have never tried in just this scheme.

Now, Professor Badger and our Office have worked at long lengths to develop something fast and noncomplicated and close to the actual experimental facility. We have done this, and now he has placed all the orders for the equipment.

And by our presence here today, I think we can urge all these companies to deliver this equipment faster to us. This will only compress the time that we can get to our tests by a matter of months, perhaps weeks. After that, we do have to run these tests. We do not know. We are not sure. We have never operated this equipment in this fashion on sea water. From Navy experience on sea water, I can tell you that there will be a lot of problems that we do not foresee today that we will just have to work out.

Mr. ASPINALL. Dr. Miller?

Dr. MILLER. We are always, of course, in a hurry to get things done, but on some things we have never been able to hurry too much.

It takes I think something like 400 days to produce an elephant. Maybe we can hurry this thing along.

And, Mr. Chairman, it takes 21 days, I think, to get an egg hatched, or something like that.

But I did want to ask Mr. Badger: What kind of energy do you use to produce your heat here?

Mr. BADGER. The two flowsheets use a very similar source. In other words, we raise steam in an ordinary garden steam boiler and use that steam to drive a turbine.

Dr. MILLER. Do you use solar heat to drive that turbine?

Mr. BADGER. No, we use just the steam from a boiler.

Dr. MILLER. Have you given any thought to using steam from a solar system?

Mr. BADGER. No, because that is too far away. We can go out and buy a boiler all wrapped up in tissue paper and tied with a pink ribbon and set it down. It is all ready to run.

Dr. MILLER. Using coal, in other words?

Mr. BADGER. Using coal or oil or what have you.

Dr. MILLER. One gentleman here spoke about the big advances in solar work.

Mr. BADGER. Well, there are only a few areas in the world where solar heat can be used, and the means of developing those on such a large scale as would be required in a steam boiler are not yet available.

Dr. MILLER. One other question. When you use this type of method, distilling the water, do you lose some of the chemicals in the water then?

Mr. BADGER. We expect to discard the concentrated sea water before any of the other salts in solution have crystallized out.

Dr. MILLER. In other words, the water will not be the flat distilled water. It would not be potable, so that you could drink it?

Mr. BADGER. We will take overhead, from the evaporators, pure distilled water. That is a product of the system.

Dr. MILLER. That would be pure distilled water?

Mr. BADGER. Pure distilled water.

Dr. MILLER. But the product you would produce for commercial use or domestic use would have some salt in the water?

Mr. BADGER. The question of how much salt is left in the product is merely a question of how much we spend on entrainment separators in the top to keep the spray from coming over.

Dr. MILLER. We recognize that certain salts are desirable.

Mr. BADGER. But we will take sea water and distill off, say, 0.9 of it. We will have one-tenth of the original sea water in the form of a strong solution of salt and what have you, that we are going to throw away. Because the substances that are present in that solution are going to cost a great deal more to get out than they are worth.

Dr. MILLER. Does freezing water take out some of those salts?

Mr. BADGER. That is one of the programs that Mr. Jenkins is working on.

Dr. MILLER. The ice in this pitcher, this ice here, is really distilled water?

Mr. BADGER. Yes.

Mr. ENGLE. Mr. Rhodes?

Mr. RHODES. Have you thought of using atomic power for heating your boiler?

Mr. BADGER. This system merely needs heat at a relatively low temperature, and the only value of atomic energy in that respect would be if you could get out of an atomic reactor this low temperature heat cheaper than you could get it from the exhaust of a turbine. It is strictly a question of cost. Any time the atomic energy people can deliver to us heat at about 500 Fahrenheit cheaper than we can get it out of a turbine exhaust, that is that.

Mr. RHODES. I am going to ask you a very fundamental question, but I do not know the answer or I would not ask it.

When water freezes, and it becomes more or less distilled water, what happens to the foreign substances which were in the water? Do they precipitate out?

Mr. BADGER. You have one fraction of the water which remains as a strong solution, and the ice is practically pure, or it should be.

Mr. RHODES. But there is no precipitation?

Mr. BADGER. If you carry your freezing far enough and have less and less of this mother liquor left, you may get it so concentrated that some of the substances will have to crystallize out. Normally those freezing processes are so carried out that all the foreign substances are kept in solution in the mother liquor.

Mr. RHODES. I gather that you feel that the apparatus which you showed us is the ultimate answer to this problem?

Mr. BADGER. That could easily be inferred from what I have said, but I do not say that at all. I will put it this way: The process that I have been talking about will give you cheap distilled water quicker than anything else I know.

Now, whether we have got the last answer, or whether some of these other processes that are under development will ultimately be better, I do not know. That is anybody's guess. This is ready now. That is the main thing I am urging before you.

Mr. RHODES. But you do feel that there should be a pilot plant built before we try to build a large scale plant?

Mr. BADGER. I want to run this pilot plant that I showed you there to study scale formation. Once I get the answer as to that, I would not hesitate to build you as big a plant as you want it. If someone feels it would be safer to build a plant for a million gallons a day, that is all right, sure.

Mr. RHODES. I was interested in the byproduct of this process, which was electric power, but I was not quite clear as to how it is brought about.

Mr. BADGER. In the normal power installation you feed into one end of your turbine high pressure steam and out of the other end of it you take steam at a very high vacuum, 28 or 29 inches. Suppose that instead of running a back pressure at 28 or 29 inches in the turbine, we dispose of the vacuum equipment and run the turbine with a back pressure of say, 5 pounds gage, it would not make quite as much juice per pound of steam as the turbine with a vacuum on it. You lose something there. But we take that 5-pound exhaust from the turbine which is generating juice to sell and use that to run the distilled water evaporators.

Now, that is an old, old principle in the chemical industries. We have hundreds and hundreds of cases where a boiler is run at high pressure and the steam is expanded through a turbine part way and lower pressure steam is taken off which is used in the process, and in some cases that may be done in even 4 or 5 steps.

For instance, I know of some chemical plants that run machines with 500-pound steam, 250-pound steam, 100-pound steam, and 25-pound steam, all of those taken off the turbine at various stages and snitching off as much juice as you can in each one of those stages from the turbine. But the principle back of it is that the value of that heat in some process cycle is worth more than the juice it would generate if you left it in the turbine to go clear down to the last vacuum.

Mr. ASPINALL. The gentleman from California, Mr. Utt.

Mr. UTT. You use a 16-million-gallon-a-day unit. From such a unit, what would be the total amount of kilowatts produced from the unit that would produce 17 million gallons of water a day?

Mr. BADGER. About 55,000 kilowatts.

Mr. UTT. Have any electric companies been approached as to whether they would be possible customers of this byproduct at a 4 mill or 5 mill or 6 mill rate at the bus bar?

Mr. BADGER. They have not. Because until I answer my basic question of: "Can I run this evaporator without scale?" I haven't wanted to shoot off my face and talk to people about something that I was not sure of. The minute I know I can build these evaporators, yes, I will talk to them.

Mr. UTT. But your testimony is that if the power could be sold at the bus bar at 6 mills, the cost of the byproduct, water, would be zero.

Mr. BADGER. Correct.

Mr. UTT. And at 4 mills it would be around $100 an acre-foot?

Mr. BADGER. Around $100 an acre-foot, around 30 cents a thousand gallons.

Mr. UTT. I think that sheds a good bit of light on our problem.

Secondly, I have another question to the gentleman in the middle—and he is the gentleman in the middle—and that is: How much area will this pilot plant in San Diego that will produce 500 gallons a day cover?

Mr. LOF. Five thousand square feet, about an eighth of an acre.

Mr. UTT. An eighth of an acre. Then in order to produce 17 million gallons a day, you would have to have pretty close to 8 thousand acres?

Mr. LOF. I have not checked your arithmetic, but it sounds about right.

Mr. UTT. It would be more than 8 thousand acres. And I was just wondering where you were going to get a thousand acres in southern California to build such a plant that would compete with this 17-million-gallon unit.

That is all, Mr. Chairman.

Mr. ASPINALL. Thank you very much, Mr. Secretary, Mr. Director, members of the staff, and contractors for having made your appearance.

We do have three witnesses from whom we have not heard.

It is impossible to state whether we may be able to arrange to hear these witnesses at some future date, but if we do we shall give you plenty of time to make those arrangements.

With that understanding the committee stands adjourned.

(Whereupon, at 12:30 p. m., the subcommittee adjourned, to reconvene at the call of the Chair.)

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